4.4.3 Tank-Farm-Facility-Specific Geology

The Tank Farm Facility was constructed within the INTEC in an area that originally had relatively deep alluvial thickness (approximately 40 ft throughout the tank farm). The alluvial material was excavated to, and in some cases into, the underlying basalt flows. Historical photographs documenting the construction of Tanks WM-180 and WM-181 show the removal of up to approximately 16 ft of the underlying basalt. Figure 4-5 is a photograph (looking west) taken in April 1951 during construction of the vaults for these first two tanks. The rebar for the base of the WM-181 vault can be seen in the foreground and concrete for the base of the WM-180 vault is in the background. The south and west sides of the excavation show the basalt outcropping and provide evidence that bedrock has been removed for construction of these two tanks. Based upon the size of the man with the white hardhat on the extreme left-hand side of the photograph and the crane, approximately 10-16 ft of bedrock were removed in the area around WM-180 and WM-181. This is supported by the depth to bedrock found in 2004 during coring in the tank farm in 28-2-sample (56 ft), 79-2-sample (60 ft), and 31-1-sample (40 ft). The coreholes in Sites CPP-28 and CPP-79 are to the south of Tank WM-181 where basalt was excavated and the corehole in CPP-31 was to the NE of WM-181 where basalt was not removed.

Few, if any, original stratigraphic controls remain in the tank farm area due to the removal of in situ materials and then backfilling the excavations. Figure 4-6 is an aerial view during tank farm construction (WM-182 through WM-184) looking south. The pillars for the WM-182 vault wall are being erected just to the right of the center of the photo. The base slab of WM-184 is visible just north of the main stack. WM-180 and WM-181 are in the peninsula of soil that is unexcavated between CPP-604 and WM-182/183. The photo shows the large amount of excavation (and subsequent backfill) associated with the construction of the tanks in the tank farm.

The movement of water and contaminants within the tank farm soils is therefore more likely controlled by construction-related layering than any original stratigraphy. Additionally, during the 2004 sampling of the tank farm alluvium, it was discovered that the particle size and compaction densities of the backfill material varied with both depth and area. For example, sampling within Sites CPP-28 and CPP-79 revealed a 2-ft-thick layer of clayey silt with remnants of surface vegetation at approximately 30 ft in depth. This layer lies directly below the top of the observed contamination of CPP-79 (deep) and may have formed a small perching layer that allowed the contamination to spread laterally. The fill within the pipe beds directly above this layer was composed of a more sorted fine-to-medium-grained sand. These “lenses” of more poorly compacted sand may also provide preferential pathways for contaminant migration.

Besides the fill materials that were used in the tank farm, the infrastructure (piping, valve boxes, tank vaults, etc.) also controls contaminant movement. Construction photos from the tank farm expansion projects indicate that the pipe in concrete trough that runs east-west through the center of CPP-31, which parallels the contamination, influenced contaminant migration both horizontally and vertically. Figure 4-7 is a photograph looking northwest during the construction of WM-187 and WM-188. The end of a stainless-steel-lined concrete trough that rests on pilings is shown just to the upper left of the center of the photo. The trough was built by the project that built WM-185 and WM-186 and similar conditions would exist in Site CPP-31. The construction of WM-187/188 had to work around that trough and eventually connect transfer lines in that trough to the new project. The trough in the photo is typical of the trough in the CPP-31 contamination site (similar size, shape, etc). The photo illustrates the difficulty in compacting and backfilling soils in the tank farm after multiple projects have excavated in the same area. Because the area under this trough and around the pilings to basalt cannot be compacted during backfilling, infrastructure like this can also create pathways for the released liquids to migrate to basalt.

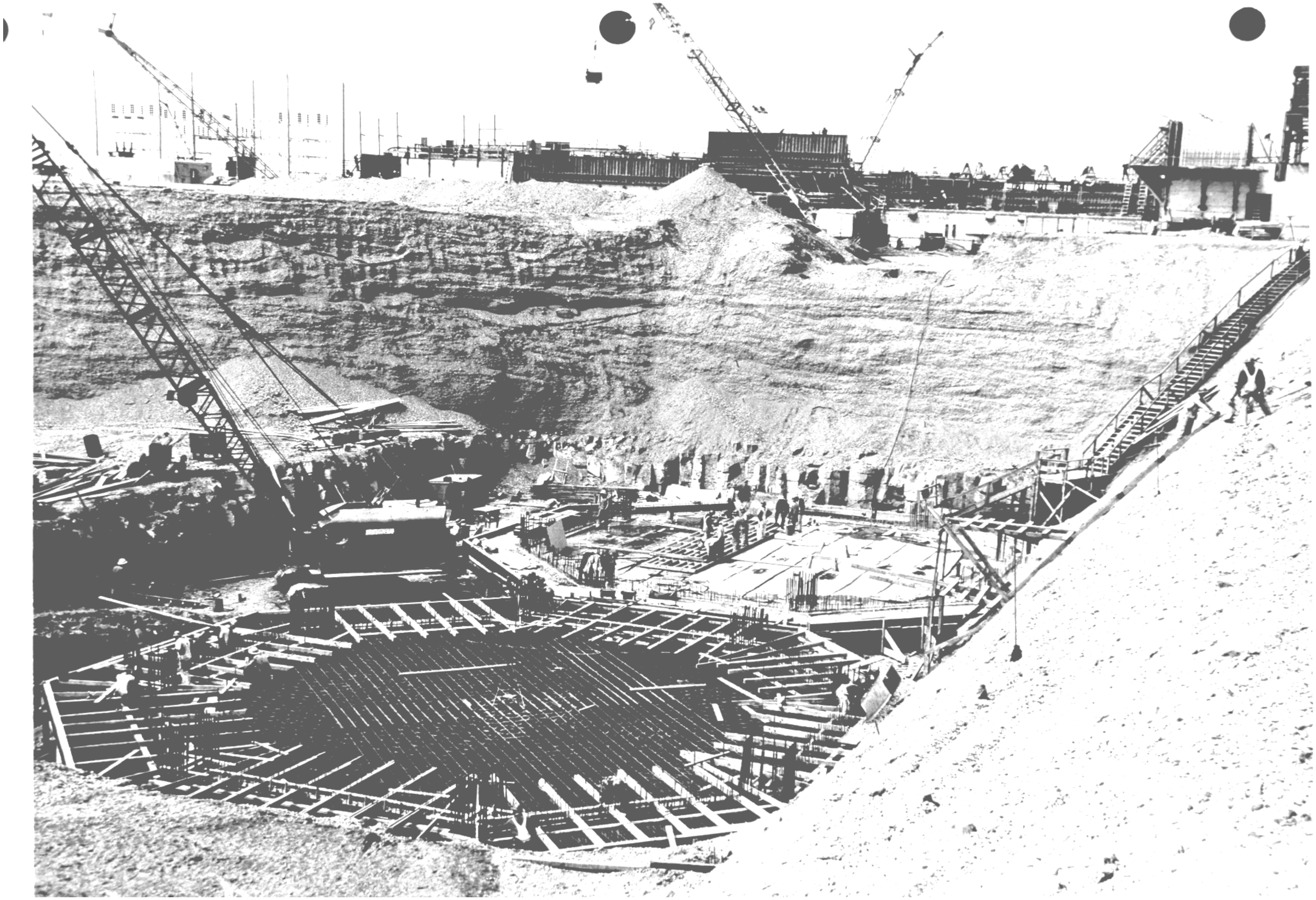

Figure 4-5. Photo showing area of excavated basalt.

Figure 4-6. Photo showing extensive excavation of tank farm alluvium.

Figure 4-7. Photo showing pipe in trough and difficulty in compacting backfill.

4.5 Summary of Hydrogeology and Subsurface Water Contamination

This section summarizes the meteorology, surface water, perched water, groundwater hydrology, and nature and extent of perched water and groundwater contamination at INTEC. The nature and extent of contamination in the perched water and groundwater were investigated under OU 3-13 Groups 4 and 5. A final remedy for perched water and an interim action for groundwater inside the INTEC fence were selected under OU 3-13. Although investigations into the physical and chemical nature and extent of contamination in the perched water and groundwater are not part of the scope of OU 3-14, a final decision for the SRPA will be made under OU 3-14. The INTEC numerical model, which forms the basis for the OU 3-14 groundwater risk assessment, uses the information gathered under Groups 4 and 5. This information is summarized below.

4.5.1 Meteorology and Climate

Meteorological data have been collected at over 40 locations on or near the INL Site since 1949. The weather station at the CFA was the first on-Site station, located approximately 5 km (3 mi) south of INTEC (Station Idaho Falls 46 W; 1949-present). Most of the meteorological monitoring is conducted by the National Oceanic and Atmospheric Administration (NOAA), and this agency maintains a large database of historical weather records. The closest meteorological station to INTEC is located approximately 1 mi north of INTEC and about 700 ft east of Lincoln Boulevard (NOAA Grid 3 tower; 1994-present). The information that follows is derived primarily from the OU 3-13 Remedial Investigation/Feasibility Study (RI/FS) (DOE-ID 1997) and the Waste Area Group (WAG) 10 RI/FS Work Plan (DOE-ID 2002a; Clawson, Start, and Ricks 1989).

The INL Site is located on the Snake River Plain, which is a large flat valley surrounded by mountains. Air masses crossing this mountain barrier lose most of their moisture before entering the Snake River Plain. Because of this rain shadow effect, the INL Site receives only about 22 cm (8.6 in.) of average annual precipitation, and the region is classified as semiarid. The semiarid climate and high land surface elevation (4,900 ft asl) of the INL Site results in rather large diurnal temperature fluctuations, with rapid solar heating of the ground surface during the day and rapid cooling at night. The surrounding mountains tend to channel the winds in the region. The prevailing winds near INTEC are from the southwest, and wind speeds are frequently greater than 8 km/hr (5 mi/hr). Wind direction frequently shifts diurnally from southwest to northeast.

Temperatures at the INL Site vary widely over the course of the year. Records for CFA indicate that the highest daily maximum temperature occurring between 1950 and 2004 was 38°C (101°F) and the lowest temperature recorded at CFA was -44°C (-47°F). The highest daily average temperature over the course of a month was 28°C (83°F) and the lowest daily average was -33°C (-28°F). Temperatures also vary greatly over the course of the day, and the average diurnal temperature range spans approximately 17°C (30°F).

Average annual precipitation at the CFA (1950 to 2004 inclusive) is 22.1 cm/yr (8.51 in./yr), and pan evaporation is approximately 109 cm/yr (43 in./yr). Over the years, the wettest months are typically in May and June. However, based on historical records, precipitation amounts of less than 0.3 cm (0.1 in.) may occur in any month. Monthly precipitation totals have ranged from zero up to 11.2 cm (4.4 in.). At the CFA station, the greatest 1-hr period or a 24-hr precipitation totals were 1.3 cm (0.5 in.) and 4.1 cm (1.6 in.), respectively. Monthly precipitation totals for CFA from March 1950 through December 2004 are summarized in Figure 4-8, along with 1994-2004 annual precipitation totals for Grid 3 tower located 1 mile north of INTEC. This histogram clearly shows the ongoing drought that has persisted from 2000 through 2004. Annual precipitation data are also included in Appendix B (Infiltration at INTEC).

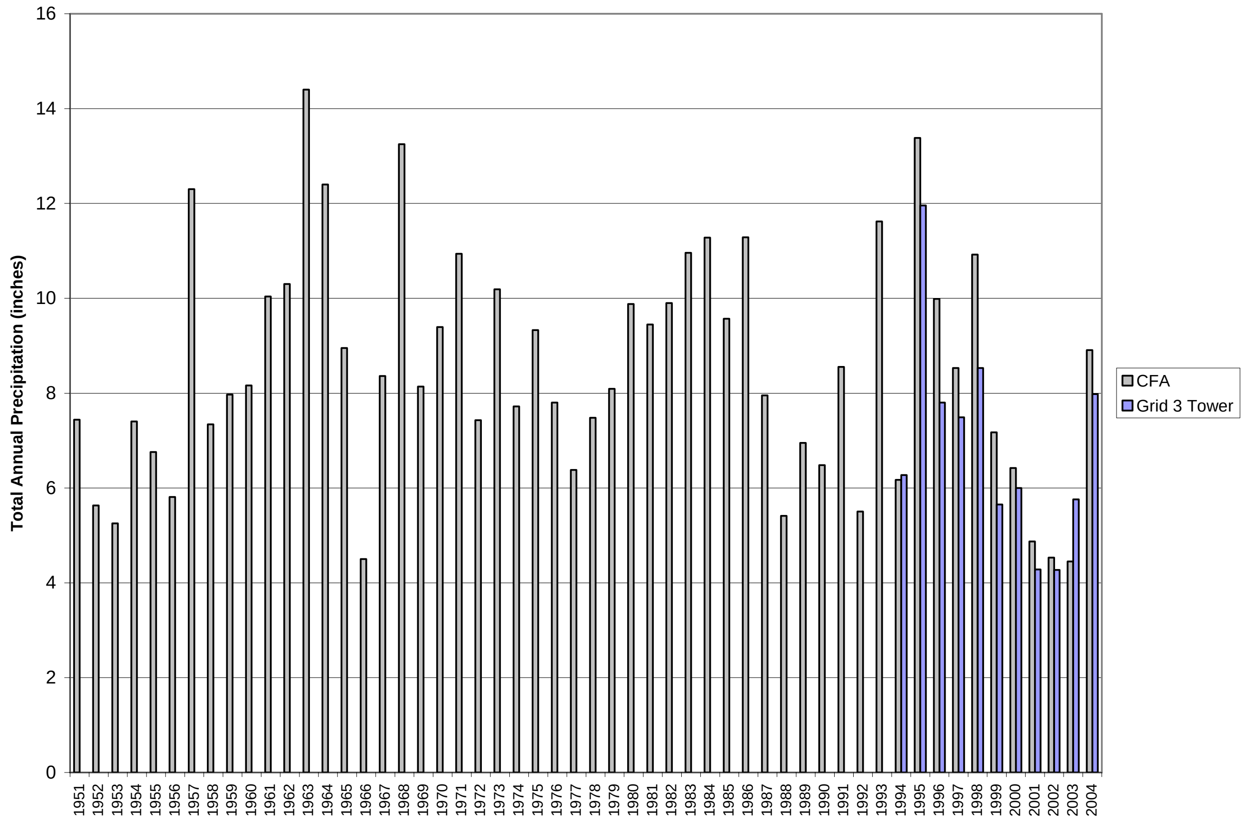

Figure 4-8. Total annual precipitation at CFA and Grid 3 tower near INTEC.

From 1950 to 1988, the CFA received an average of 70.1 cm (27.6 in.) of snow per year. The maximum snowfall in a year was 151.6 cm (59.7 in.). Maximum snowfall occurs in December and January. Little snow falls from May through October. June, July, and August are the only months with no recorded snowfall between 1950 and 1988. The maximum snowfall in a 24-hr period was 21.8 cm (8.6 in.), which occurred in March. A snowfall of 21.6 cm (8.5 in.) in a 24-hr period is recorded for January. The lowest annual snowfall at the CFA was 17.3 cm (6.8 in.). All months have gone without snowfall in at least 1 year during the period of record.

Average daily relative humidities at the CFA range from 30 to 70%. Relative humidities typically are higher during the colder months (November through March). Relative humidities on summer afternoons are frequently lower than 15% and can drop below 5%.

From 1950 through 2004, the average air temperature at CFA in January (the coldest month) was -8.6°C (16.6°F). During July, the warmest month, the temperature averaged 20.1°C (68.2°F). The annual average temperature was 5.7°C (42.3°F).

Severe weather on the INL Site consists of thunderstorms, tornadoes, and funnel clouds. On average, two to three thunderstorms occur during each of the summer months. Small hail may accompany the thunderstorms but hail damage has not been reported at the INL Site. Since 1949, three small tornadoes have occurred within the boundaries of the INL Site, but these caused no damage. In addition, funnel clouds have been observed on several occasions, but no INL Site facilities have ever been damaged by a tornado. Dust devils are also common in the region and can entrain dust and pebbles several hundred meters (feet) in the air. Dust devils usually occur on warm sunny days with little or no wind.

4.5.2 Surface Water

Surface water sources at INTEC have included (1) the BLR (when flowing), (2) infiltration of rain and snowmelt, (3) the former percolation ponds (taken out of service August 2002), and (4) the former Sewage Treatment Plant infiltration trenches (taken out of service December 2004). These recharge sources are discussed below.

4.5.2.1 Big Lost River. The BLR is the major surface water feature within the INL Site. The channel of the BLR lies within 100 ft of the northwest corner of the INTEC facility (Figure 4-9). The average elevation of the INTEC facility (4,917 ft) is about 9 ft higher than the elevation of the BLR channel immediately to the northwest and is about 5 ft higher than the elevation of the BLR bank or berm (4,912 ft).

The BLR is an intermittent stream that flows north through the INL Site to its terminus at the Big Lost River sinks, where all of the water infiltrates into the ground. A hydrograph of historical BLR flow rate (discharge) at the USGS gaging station at Lincoln Boulevard is shown in Figure 4-10. This gaging station is located near the northwest corner of the INTEC facility. As a result of a continuing drought, no flow has occurred in the BLR at INTEC from May 2000 through the end of 2004. When flow does occur, peak flows are typically in June and July due to snowmelt, and there is often no flow in the river during the winter months.

BLR flows are regulated at Mackay Reservoir, which is located approximately 40 miles to the northwest of the INL Site. Flows that reach the INL Site may be diverted at the INL Site diversion dam to flow to the flood control “spreading areas” located southwest of RWMC. Water that is not diverted to the spreading areas continues to flow northward across the INL Site in a shallow channel to its terminus at the Lost River sinks. Flow in the sinks is lost to evaporation and infiltration. Additional details and references that discuss the BLR drainage areas, the INL Site diversion dam, and spreading areas can be found in the OU 3-13 Remedial Investigation/Baseline Risk Assessment (RI/BRA) report (DOE-ID 1997).

When it is flowing, the BLR constitutes a significant source of recharge to perched water and the aquifer. Flow in the BLR depends on winter snowpack conditions and whether controlled releases are occurring from Mackay Reservoir. Figure 4-10 shows the mean monthly discharge (flow rate) for the BLR at the Lincoln Boulevard gaging station at INTEC during the period 1984 to 2005. The river flowed for extended periods during the wet years of 1984 to 1987 and again during 1995 to 2000. The BLR was dry from May 2000 through May 2005 as the result of a 5-year drought. However, due to above-normal snowpack during the winter of 2004-2005, a brief period of river flow occurred at INTEC during May 29 - June 8, 2005.

When the BLR does flow, some of the river water infiltrates into the gravelly sediments beneath the river, and most of this streamflow infiltration water eventually recharges the SRPA. Streamflow infiltration rates of 1 to 2 cubic feet per second (cfs) per mile of river channel have been reported by the USGS for low flow conditions (<100 cfs) in the reach between Arco and the BLR Sinks (Bennett 1990). At higher river flows, higher streamflow infiltration rates occur. At a flow rate of 372 cfs, infiltration losses were reportedly approximately 8 cfs/mile in the reach that includes the Lincoln Boulevard gaging station near INTEC (Bennett 1990).

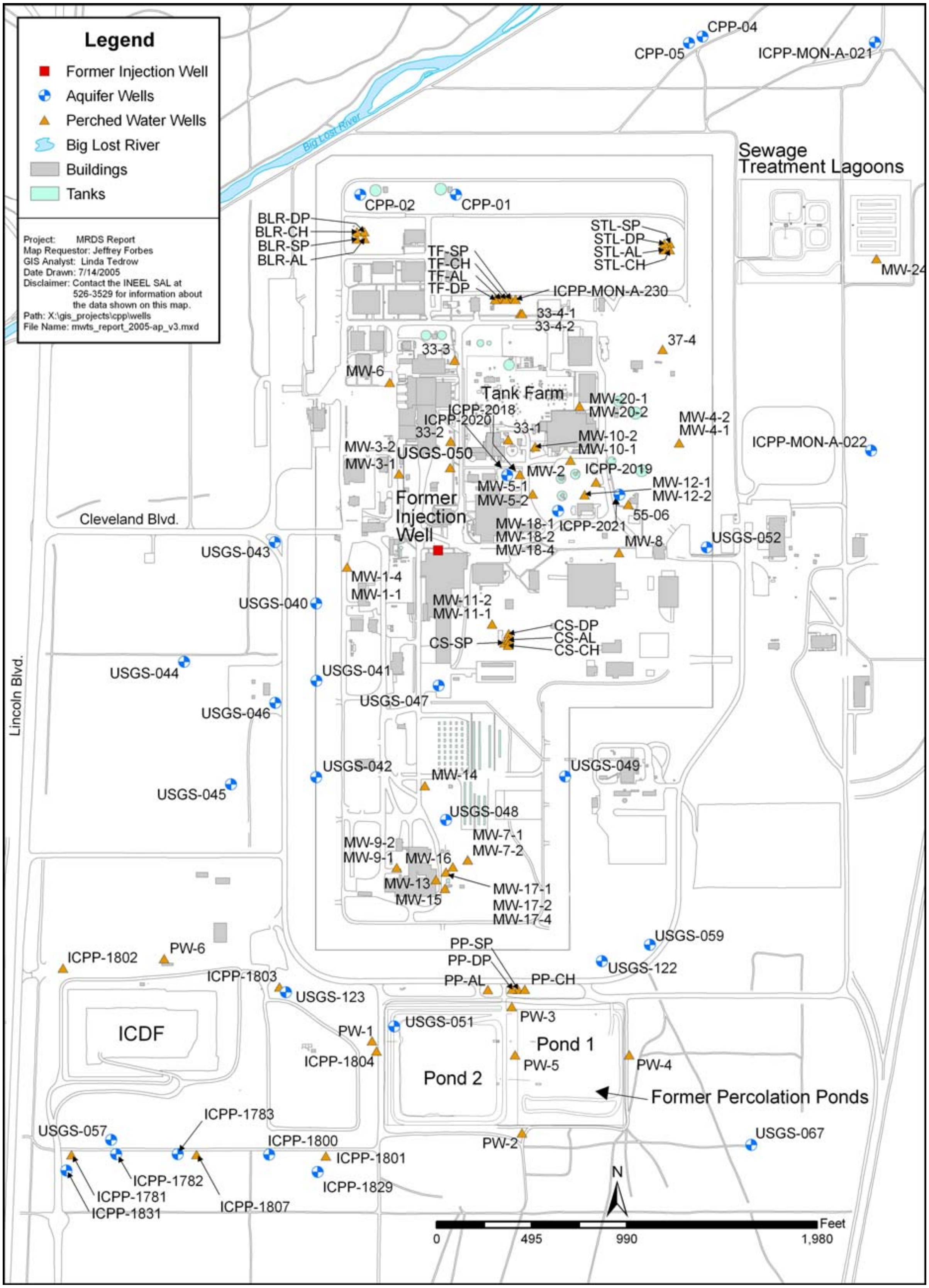

Figure 4-9. INTEC well locations.

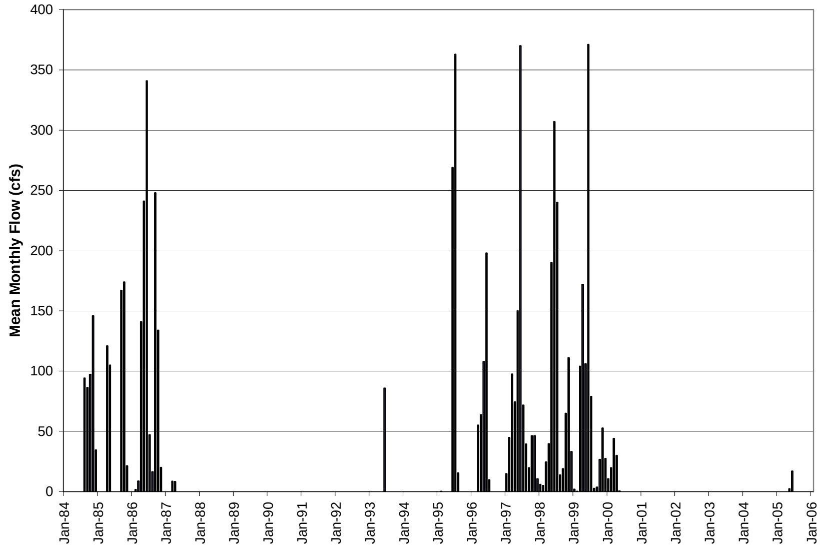

Figure 4-10. Big Lost River hydrograph 1984–2005.

The INTEC vadose zone model assumed that the average infiltration rate for the BLR for the period 1984-2003 was approximately 7.5 cfs (1,066 kg/day per meter river length) (Appendix A). Losses due to evapotranspiration are small in comparison to infiltration losses. Significant amounts of groundwater recharge occur into the coarse alluvium of the channel bed during periods of flow in the BLR, and groundwater levels may rise many feet over much of the INL Site following the onset of flow in the BLR.

While BLR streamflow infiltration undoubtedly contributes greatly to aquifer recharge, recent information suggests that the BLR is not the most significant recharge source in terms of contaminant transport in the upper shallow perched water near the tank farm. For example, only one upper shallow perched well (BLR-CH) showed a significant change in water level during and following the June 2005 BLR flow event. This well is located within 200 ft of the BLR channel, in the extreme northwest corner of INTEC. Perched wells located in contaminated areas near the tank farm showed no such response. The limited southeasterly lateral flow of streamflow infiltration at the depth of the upper shallow perched water is likely in part due to the northwest dip of the 110-ft sedimentary interbed in the northwestern portion of INTEC.

An analysis of well hydrographs for the period 1995-2005 demonstrates that changes in upper shallow perched water levels are primarily caused by infiltration of rain and snowmelt, rather than BLR streamflow infiltration recharge (DOE-NE-ID 2005b). The current vadose zone TETRAD model appears to confirm this conclusion (DOE-NE-ID 2005c). In summary, it appears that, although streamflow infiltration contributes to recharge of the deep perched water and the aquifer, the effect of the BLR on mobilization of radionuclide contaminants in the upper shallow perched water near the tank farm appears to be minimal.

4.5.2.2 Precipitation Infiltration. Rain and snowmelt periodically infiltrate into the gravelly alluvium in and around the INTEC facility. Even though average annual precipitation (22.1 cm/yr) is much less than the pan evaporation rate (109 cm/yr), water from snowmelt or heavy rains can and does infiltrate into the ground to depths where it cannot evaporate. This water then continues to move downward until it recharges perched water and the aquifer.

The combination of coarse surficial sediments and lack of vegetation permits infiltration of a large fraction of the natural precipitation. Furthermore, many areas at INTEC are occupied by buildings, or are paved with asphalt or concrete. Precipitation falling on building roofs is routed to downspouts. Water falling on paved surfaces tends to flow laterally to the pavement edge, where it may then flow into drainage ditches. The ditches are mostly unlined, and a significant fraction of infiltration is likely to occur along the ditches. Therefore, infiltration may actually be greater due to the impervious areas, which act to focus much of the surface runoff into gravelly areas or unlined drainage ditches.

That high infiltration rates occur at INTEC is supported by several infiltration tests, the performance of the former percolation ponds, and other historical observations. These observations and results are described briefly below. During 1982, the USGS performed percolation tests at INTEC to investigate the possibility that the 1+ mgd service waste flow could be disposed to surface infiltration basins (percolation ponds), instead of the INTEC injection well that had been used for this purpose up until that time. Percolation tests were performed at two locations, including the Service Waste Percolating Pond (SWPP) southeast of the facility and the gravel pit located immediately east of INTEC (CPP-37A). The results of these tests were reported by Barraclough (1983) and indicate infiltration rates of 12 gpd/ft^2 (1.6 ft/d) at the SWPP and 52 gpd/ft^2 (6.9 ft/d) at the east gravel pit. These results demonstrated that water can infiltrate very rapidly through the alluvium at these locations. Based on these findings, the two former percolation ponds were constructed in 1983 at the SWPP location south of INTEC. The wetted bottom areas of the east and west percolation ponds were 2.76 and 4.42 acres, respectively. From 1984 through 2002, these two ponds received between 1 and 2 mgd of service waste. These flow rates resulted in large infiltration rates (>1 ft/day) at the former percolation ponds.

In 1993, two infiltration tests were performed near the northeast corner of INTEC (INEL 1995a). The first infiltration test consisted of a 10-ft-radius circular infiltration pond constructed around Well A-68. The basin was filled with 750 gal of water to a 3.8 in.-depth and monitored for 72 hours. The wetting front reached the 10-ft depth after 2 hours, the 19-ft depth after 20 hours, and the top of basalt at 30-ft depth after 40 hours. The test demonstrated rapid movement of the wetting front through the alluvium to the bedrock surface.

A second test consisted of a ponded infiltration test performed at neutron access tube A-67 (INEL 1995a). A small semicircular basin was constructed around A-67 (120 degree arc around well; inner radius 7 ft from well; outer radius 15.8 ft from well). Five hundred gallons of water were added to the basin, which resulted in a water depth of 3.8 in. Neutron logging was performed at A-67 over a period of 72 hours. The wetting front was never observed at access tube A-67, and it was concluded that the water moved rapidly vertically downward through the alluvium, with very little lateral movement.

Neutron moisture logging was performed monthly during 1994 in the A-series and 81-series cased boreholes located within and near the tank farm. In order to refine estimates of precipitation infiltration rates in and around the tank farm, the neutron logs were reevaluated using the UNSAT-H computer model (Appendix B) to assess soil moisture profiles and downward wetting front migration during the 1994 spring snowmelt. The UNSAT-H code simulates the dynamics of water movement through the vadose zone as a function of meteorological conditions and soil hydraulic properties. A conclusion from this analysis is that the rate of precipitation infiltration at and near the tank farm is likely larger than previously believed. It was concluded that the recharge rate inside the INTEC security fence may be approximately 18 cm/year, which constitutes 85% of the average annual precipitation (22 cm/yr). This infiltration rate is nearly double the value of 10 cm/yr assumed by the OU 3-13 RI/BRA vadose zone model (DOE-ID 1997). Another conclusion is that the tank farm membrane cover is no longer effective in preventing infiltration of water and, most likely, has the effect of focusing the water infiltration at membrane breaches and tears, and along the liner perimeter. Additional details are provided in Appendixes A and B of this report.

Perched water monitoring also corroborates the rapid infiltration and downward movement of water through the vadose zone. One example is the accumulation of water in deep perched monitoring well ICPP-1802 following the spring thaw snowmelt. This well is screened from 363 to 383 ft bgs and was dry for nearly 2 years following its installation in 2002. During the winter of 2003-2004, large piles of plowed snow accumulated in the vicinity of this well. Warm temperatures during February 17-23, 2004 caused rapid melting of snow. On February 24, 2004, large areas of ponded melt water were observed in the gravel parking lot near the well. Sounding of the well revealed that a small amount of deep perched water had accumulated in the well, most likely as a result of infiltration of the melt water at the surface. Though the amount of water in the well was too small for sampling, this observation is consistent with previous information that demonstrates that ponded surface water can infiltrate to depths of hundreds of feet within a matter of weeks at INTEC. Additional efforts to quantify infiltration rates and perched water sources are being performed as part of the OU 3-13 Group 4 remedial action (DOE-ID 2006a).

Over the years, several efforts have been made to reduce infiltration of precipitation that falls within the INTEC facility. One such activity was the installation of an impermeable polyolefin plastic cover over the surface of the tank farm in 1977 to prevent infiltration of water (DOE-ID 2004a). The membrane was laid in individual sections and was drawn up and fitted around aboveground structures, and the seams were sealed. During the years following its installation, however, the tank farm cover has reportedly been cut or breached numerous times during construction activities, and it is generally believed that the cover is no longer effective in preventing infiltration of precipitation (Appendix A).

A recent project to reduce infiltration in the northern part of INTEC was completed in 2004 as part of the Tank Farm Interim Action (TFIA) (DOE-NE-ID 2005a). This work included grading and constructing new ditches, lining the existing ditches with concrete, installing a trench drain along Beech Street, replacing existing culverts with larger culverts to accommodate the expected increase in storm water flow, and constructing a large double-lined storm water evaporation pond outside the INTEC fence immediately east of the facility. In addition, areas inside the tank farm were covered with asphalt, including CERCLA soil contamination areas CPP-31, CPP-28, and CPP-79. Unpaved/gravel surfaces within the tank farm and surrounding the tank farm were sealed with asphalt to prevent water infiltration and divert surface water toward the storm water collection system. Additional areas outside the tank farm were covered with asphalt to route runoff to nearby lined storm water collection ditches.

Based on an analysis of downhole neutron moisture logs performed at the INTEC tank farm during 1994, the annual precipitation infiltration rate inside INTEC has recently been estimated at approximately 18 cm/yr (7.1 in./yr) or about 85% of the total average annual precipitation (Appendix B). The total fenced area of INTEC is approximately 175 acres. Therefore, precipitation infiltration for the entire facility totals approximately 34 mgy. Perhaps 20 mgy of this total would be expected to recharge the northern perched water, which contains the highest concentrations of radionuclides. This volume is comparable to estimates of the upper shallow perched water volume (6 to 18 M gal). Taken together, this information indicates that the upper shallow perched water is being continuously replaced by recharge, and the mean residence time for the upper shallow perched water is likely less than 1 year.

An analysis of perched water levels in northern INTEC monitor wells shows a strong positive correlation with precipitation infiltration (DOE-NE-ID 2005b). Figure 4-11 shows inferred upper shallow perched water volume changes (calculated from observed water levels), along with hydrographs of precipitation and BLR flow at INTEC. The degree of correlation between the timing of upper shallow perched water level changes and calculated “relative soil moisture” strongly indicates that seasonal water level changes are primarily caused by infiltration of rain and snowmelt, rather than BLR streamflow infiltration recharge (DOE-NE-ID 2005b).

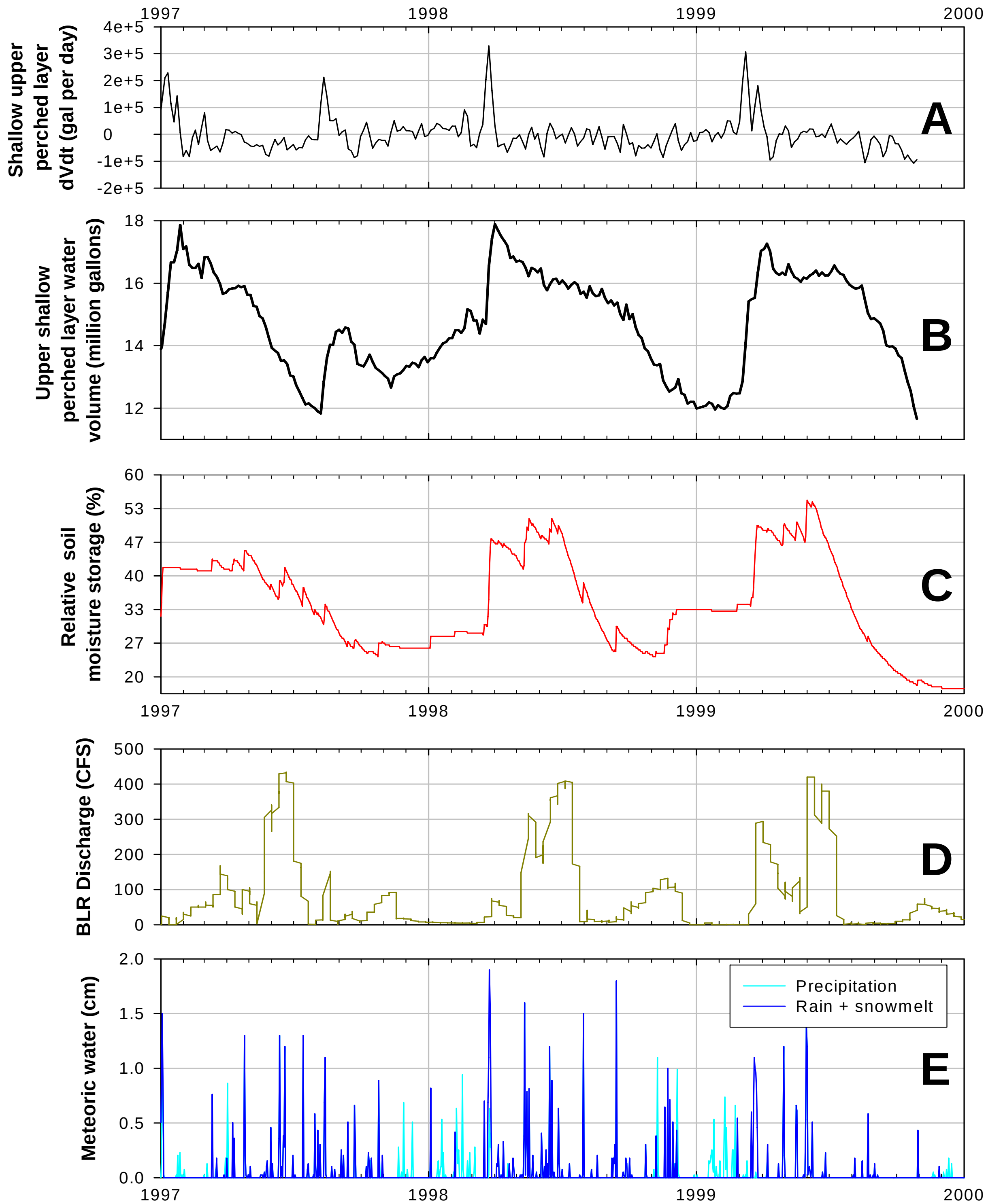

Figure 4-11. Response of upper shallow perched water to precipitation infiltration and Big Lost River. (Refer to Appendix C in DOE-NE-ID [2005b] for details.)

4.5.2.3 Anthropogenic Water Infiltration.

Anthropogenic water includes intentional clean water discharges to ground and accidental water leaks from underground water pipelines. The *INTEC Water System Engineering Study* (WSES) (DOE-ID 2003b) provides a detailed description of the INTEC water system. The primary water systems include raw water, fire water, treated (softened) water, demineralized water, steam condensate, landscape watering, potable water, service waste (industrial wastewater), and sanitary waste systems. Piping systems outside of facility buildings are either buried or enclosed in utility tunnels. It has been estimated that about 23 km (14 mi) of water pipelines are present at INTEC.

There are two separate water systems at INTEC, one for process water (treated, raw, and demineralized) and another for potable water. During 2004, daily process water usage at the INTEC facility averaged about 1.3 mgd. Process water is obtained from production wells CPP-01 and CPP-02 in the northwest corner of the facility (Figure 4-9), and pumping alternates monthly between these two wells. Most of the process water leaves the facility as "service waste," which then flows to the new percolation ponds located about 2 miles west of INTEC. The difference between process water pumpage (inflow) and service waste flow (outflow) includes both evaporation and infiltration that occurs within the facility. Evaporative losses occur at (1) CPP-603 and CPP-666 spent fuel storage pools, (2) evaporative coolers, (3) steam discharges, and (4) evapotranspiration from irrigated lawns and dust suppression watering. Infiltration losses of process water may result from (1) discharge of process water to unlined ditches and drains, (2) overwatering of lawns, (3) application of excess dust suppression water, and (4) process water line leaks.

Prior to 1983, potable water was obtained from the same wells as the process water (CPP-01 and CPP-02). However, repeated occurrence of radionuclide contamination of these two wells by service waste disposal to the injection well (CPP-03) resulted in the installation of new potable water supply wells CPP-04 (drilled 1983) and CPP-05 (drilled 1991) (Rhodes 1960, Johnson 1968, Rhodes 1970, Amberson 1970, Barraclough 1978). Since 1983, all potable water has been obtained from supply wells CPP-04 and CPP-05 located just outside the INTEC security fence near the northeast corner of the facility. Groundwater at these two wells has never exceeded maximum contaminant levels (MCLs) for any contaminant of concern (COC).

During 2004, potable water usage was approximately 40,000 gpd, which amounts to only about 3% of process water use. Most of the potable water is returned to the Sewage Treatment Plant located in the northeast corner of INTEC (Figure 4-9). Some water evaporates at the Sewage Treatment Plant during the aeration wastewater treatment process, and the remainder of the treated effluent is discharged to the ground. Prior to December 2004, the treated wastewater effluent flowed to four infiltration trenches located immediately east of the Sewage Treatment Plant. As part of the Sewage Treatment Plant upgrade project, the wastewater effluent pipeline was connected to the service waste line on December 2, 2004. Since that date, the treated wastewater effluent flows with the service waste to the new percolation ponds 2 miles west of INTEC. Although most of the potable water returns as wastewater to the sewage treatment plant, a smaller amount is discharged to septic systems and leachfields that serve several buildings in the central and southern portion of INTEC (CPP-626, CPP-655, CPP-656; see Figure 3-2 in DOE-ID 2003b).

Over the years, several attempts have been made to calculate water balances or budgets for the INTEC facility. One of the earliest efforts reported by Amberson (1970) included a water budget for a 1-month period in 1970. Based on the observation that the difference between inflow (pumpage) and outflow (injection well) was only 190,000 gal (0.4% imbalance), the study concluded that there were no significant leaks in the underground piping at that time.

Another early water balance was reported by Robertson, Schoen, and Barraclough (1974). This study reviewed the annual pumpage and wastewater discharge records for the period 1959-1970. On average, the annual water volume pumped exceeded annual volume of wastewater discharged by about 15%. Over the 10-year period, it was estimated that 557 M gal of water were unaccounted for, and a portion of this amount was ascribed to system leaks to the subsurface.

WINCO (1994) performed a Water Inventory Study to determine whether water was leaking from the plant's water and wastewater systems at sufficient rates to recharge the perched water zones that exist beneath the facility. A thorough evaluation of the primary piping systems was performed, and leaks were discovered in the fire water and potable water pipelines. The fire water system was found to have a year-round leak of 15 L/min (4 gpm) and an additional leak of 45.4 L/min (12 gpm) in a branch connection that was only used periodically. The potential loss from the fire water systems was determined to be 14.8M L/yr (3.9 mgy or 7.4 gpm). The potable water system was found to have a small leak of 0.57 L/min (0.15 gpm), which would provide approximately 299,000 L/yr (79,000 gpy) of potential recharge to the perched water systems. These leaks were later repaired (DOE-ID 2003b) but, historically, may have allowed significant volumes of recharge to the perched water. As noted in the past, the potential exists that additional unknown leaks may be present in the 23 km (14 mi) of underground piping (DOE-ID 1997). For example, assuming an annual process water pumpage of 500 M gal, and flow meter precision of ± 5%, an annual loss of 25 M gal could go undetected.

Another purpose of the Water Inventory Study (WINCO 1994) was identification of the source of water infiltrating into tank farm vaults. Seepage into the vaults was of concern because the water could potentially transport radionuclide contaminants to soil and groundwater. The rate of seepage into the vaults was found to be approximately 109,780 L/yr (29,000 gpy). Potential sources of this water were evaluated based on the seasonal variability of seepage, chemistry of the water, location of the sources, and volume of water available for seepage from a particular source. The two most important sources of water for seepage were determined to be infiltration of precipitation and watering of the lawn to the west of Building CPP-699 located immediately east of the tank farm. These findings suggested that the existing membrane cover over the tank farm was ineffective in preventing precipitation infiltration into the vaults.

Between 2002 and 2004, several previously significant sources of subsurface recharge at INTEC have been reduced or eliminated. On August 26, 2002, the two percolation ponds located immediately south of INTEC were permanently taken out of service. Since that date, the 1+ mgd service waste flow has been sent to the new percolation ponds located about 2 miles west of INTEC. The relocation of the percolation ponds in 2002 represents a large reduction in subsurface recharge and resulted in rapid drain out of perched water beneath much of the southern part of INTEC (Cahn and Ansley 2004). However, the relocation of the percolation ponds has had essentially no effect on perched water levels in the northern part of INTEC (DOE-NE-ID 2004b).

On December 2, 2004, the Sewage Treatment Plant wastewater effluent discharge line was tied into the service waste line, and the treated wastewater effluent began flowing to the new percolation ponds 2 miles to the west of INTEC. At the same time, the four wastewater infiltration trenches near the northeast corner of INTEC were permanently taken out of service. This change reduced infiltration rates in the northern part of INTEC by up to 40,000 gpd.

Subsurface injection of waste steam condensate has also been significantly reduced in recent years. Furthermore, infiltration from landscape irrigation has been reduced as a result of elimination of several grassed lawn areas within the facility. Current estimates of infiltration from steam condensate and landscape irrigation are discussed in the Water System Engineering Study report (DOE-ID 2003b) and the WCF Vicinity Discharges Elimination Work Plan (DOE-NE-ID 2004c). A follow-up report (DOE-ID 2005a) was prepared in 2005 and contains an updated INTEC water balance for 2005.

A Water System Engineering Study was conducted in 2003 to identify and quantify anthropogenic recharge sources associated with INTEC operations. However, due to inadequate metering, process water flow data were deemed inadequate to complete a defensible water balance. Subsequently, plant metering systems were upgraded during 2004, and water balance calculations were completed for the first half of 2005 (DOE-ID 2005a). The water balance report concluded that

- About 1% of overall water use at INTEC is discharged to ground from known leaks.
- About 0.5% of overall water use at INTEC is discharged to ground from intentional discharges (includes irrigation, septic discharges, fire water operational discharges, etc.).
- About 9% unaccounted water (including unknown leaks).

The worst-case scenario, then, would be to assume that all "unaccounted water" is discharged to ground via unknown underground pipeline leaks. Under this scenario, and ignoring evaporation, anthropogenic recharge could total up to 10.5% of overall INTEC water usage. Total plant water usage for 2004 was approximately 495 M gal, with potable water use being about 8 M gal of this total. Therefore, the maximum possible anthropogenic recharge rate would be 52 mgy. The actual magnitude of anthopogenic infiltration is likely much lower. This worst-case scenario assumes that (1) all unaccounted water goes to ground, (2) the data from the 6-month water balance are typical, and (3) 2004 total water usage is typical. The maximum possible annual anthropogenic recharge (52 mgy) is larger than the current estimate of facility-wide precipitation infiltration (34 mgy). Based on the higher density of utilities and activities in the northern portion of INTEC, the majority of anthropogenic recharge is believed to occur in this same general area. Even if anthropogenic recharge is assumed to include only the known 2005 discharges and leaks (1.5% of water use), this volume (~7 mgy) is approximately equal to the volume of the upper shallow perched water. Therefore, the mean residence time for water in the upper shallow perched zone must be short, probably less than 1 year.

4.5.3 Nature and Extent of Perched Water Contamination

Perched water zones have been present at various depths within the 460-ft-thick vadose zone beneath INTEC since at least as early as 1956 (Robertson, Schoen, and Barraclough 1974). Perched water monitoring and remediation at INTEC are being performed under WAG 3, OU 3-13, Group 4 (Perched Water). A remedy for the perched water has already been established in the OU 3-13 ROD (DOE-ID 1999b), and, therefore, the perched water is outside the scope of the OU 3-14 RI/FS. However, the perched water constitutes the link between the surficial alluvium and the groundwater in the SRPA, and both the alluvium and the SRPA are within the scope of OU 3-14. Information on the nature and extent of perched water beneath the INTEC is an integral part of the conceptual and numerical models to explain behavior of contaminants released from the OU 3-14 and 3-13 sites as the contaminants migrate toward the SRPA. For these reasons, a discussion of perched water at INTEC is included below.

The OU 3-13 ROD requires that perched water zones be monitored to assess perched water drain out and downward contaminant flux to the SRPA (DOE-ID 1999b). The *Long-Term Monitoring Plan for OU 3-13, Group 4 Perched Water* (DOE-ID 2005b) specifies the wells to be sampled and the required field and laboratory parameters, based on the requirements in the OU 3-13 ROD. Perched water data quality objectives are described in the Monitoring System and Installation Plan (MSIP) for Group 4 (DOE-ID 2005c). Perched water investigations and results obtained through 2002 were previously summarized in a report entitled *Phase I Monitoring Well and Tracer Study Report for OU 3-13, Group 4 Perched* (MWTS) (DOE-ID 2003a), and much of the following discussion is derived from that report.

Perched water has formed in two distinct geographic areas: northern and southern INTEC. The northern perched water system consists of the shallow and deep perched water zones. The lateral extent of the northern shallow perched water system is shown in Figure 4-12 and has been further divided into the

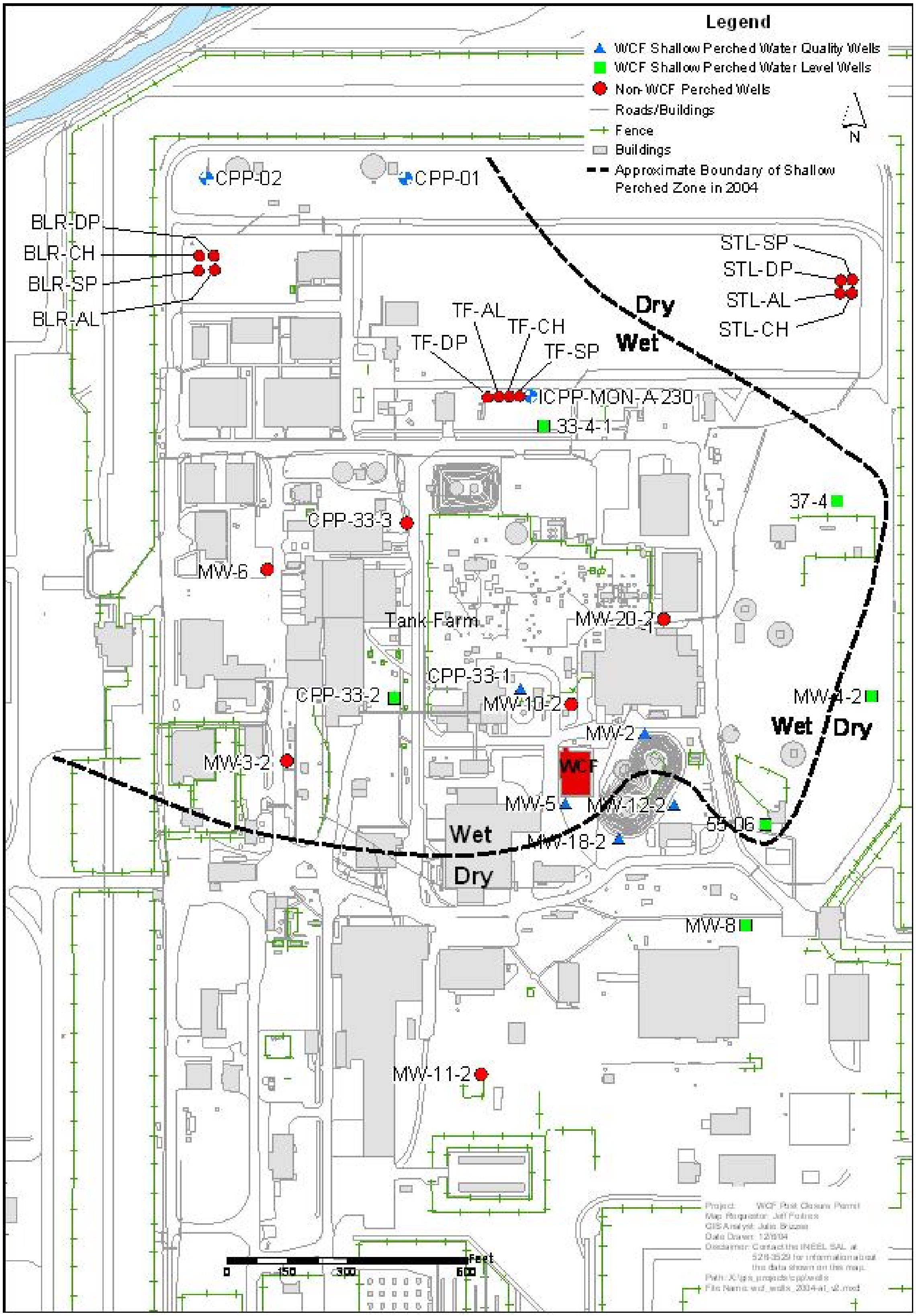

Figure 4-12. Approximate lateral extent of northern shallow perched water beneath INTEC during 2004.

upper shallow and lower shallow perched zones, which generally correspond with the 110- and 140-ft sedimentary interbeds that underlie the site. The deep perched zone coincides with the 380-ft interbed. The southern perched water system includes three main perching zones at depths of approximately 110, 250, and 380 ft bgs when the former percolation ponds were in service.

Based on the distribution and geochemistry of the perched water, the northern and southern shallow perched water systems appear to be discontinuous, with separate recharge sources. Several shallow perched monitoring wells in the central portion of INTEC are dry or only intermittently have water, indicating that the northern and southern zones are not contiguous. These observations also suggest that the primary recharge sources are located in the northern and southern portions of INTEC.

The perched water contaminant of greatest environmental concern at INTEC is Sr-90. The reasons for this include (1) Sr-90 is abundant in SNF (6% fission yield); (2) Sr-90 can remain somewhat mobile under certain subsurface conditions (unlike many other fission products); (3) Sr-90 has a long enough half-life (29 yr) that it persists for hundreds of years, yet short enough that it has a high specific activity; and (4) the drinking water standard for Sr-90 is relatively low (MCL = 8 pCi/L). The total (undecayed) inventory of Sr-90 in the known historical liquid releases at the tank farm is approximately 18,000 Ci (DOE-NE-ID 2005c). As a result of the factors listed above, Sr-90 is the constituent whose concentrations most greatly exceed its MCL in perched water at INTEC and, therefore, presents the greatest threat to groundwater quality in the underlying SRPA. Other radionuclides present in perched water include Tc-99, I-129, tritium, and Cs-137. However, because the concentrations of these other constituents are close to, or below, their respective MCLs, they are of considerably less environmental concern, compared to Sr-90.

4.5.3.1 Northern Shallow Perched Water. The northern perched water system is more complex than the southern perched water system in that the recharge sources are not as apparent. In the northern INTEC, the most obvious recharge sources include the BLR at the northwest corner of the facility and the Sewage Treatment Plant infiltration trenches located to the northeast. However, the BLR did not flow from May 2000 through May 2005, and the Sewage Treatment Plant effluent was routed to the new percolation ponds in December 2004. Therefore, as of the end of 2004, the BLR and Sewage Treatment Plant were not contributing to perched water recharge. Nevertheless, the northern shallow perched water has continued to persist, and other recharge sources must therefore be responsible. As discussed in Section 4.4.2, the continued presence of perched water beneath the northern portion of INTEC is attributed to the accumulation of natural precipitation infiltration and process water leaks and discharges on top of low vertical hydraulic conductivity zones.

Perched water has not generally been observed at the alluvium/basalt contact beneath the northern INTEC. However, flow in the BLR would be expected to cause some lateral spreading of water at the bedrock surface. The alluvium/basalt contact slopes to the southeast from the BLR channel toward a depression in the central part of INTEC (DOE-ID 2003a). Water moving into the basalt most likely continues vertically downward with minor lateral spreading until it encounters the 110-ft interbed, where vertical flow is impeded. The northern shallow perched water then moves laterally along the 110-and 140-ft interbeds and adjacent basalt flows, until it finds vertical pathways to the deeper vadose zone and eventually to the aquifer.

Perched water quality results are summarized in the 2004 annual perched water monitoring report (DOE-NE-ID 2004b). Results for 2003 were included in a similar report (DOE-ID 2003c). Strontium-90 and tritium were the principal radionuclides detected in perched water at concentrations exceeding their respective MCLs. Perched water results in this report are compared to drinking water MCLs. Such comparison is for reference only and does not imply that the perched water zones constitute aquifers capable of sustained long-term yield.

The northern shallow perched water contains the highest radionuclide concentrations at INTEC, with Sr-90 being the principal COC. Sr-90 was detected at concentrations much higher than any other radionuclide and was present in nearly all of the northern perched water wells. Eleven of the 22 perched water wells sampled during 2004 exceeded the Sr-90 MCL of 8 pCi/L. The highest Sr-90 concentrations were observed in upper shallow perched wells located southeast of the tank farm, in particular, monitoring wells 33-1, MW-2, MW-5, and 55-06. Because no monitor wells have ever been installed directly beneath the tank farm, even higher concentrations could possibly be present in perched water there. Lower radionuclide concentrations are observed to the northwest of the tank farm (toward the BLR) and to the northeast (toward the Sewage Treatment Plant).

The maximum Sr-90 concentrations detected in 2004 in the northern shallow perched zone were 458,000 pCi/L (Well 33-1); 160,000 pCi/L (MW-2); 25,800 pCi/L (55-06); and 16,100 pCi/L (MW-5-2). Lower shallow perched well MW-20-2 also contained elevated Sr-90 (17,200 pCi/L). Sr-90 concentrations in the northern shallow perched water wells were similar to those observed in 2003 in most of the wells (DOE-ID 2003c). Except for Sr-90, the concentrations of other fission products (Tc-99, I-129, and Cs-137) in the northern shallow perched water did not exceed MCLs during 2004. Likewise, the concentrations of actinides were below MCLs (Pu, Am, Np) (DOE-NE-ID 2004b).

During 2004, Wells MW-2, 33-3, and MW-5 had the highest perched water temperatures of approximately 21.2, 20.0, and 18.7°C, respectively, while most other perched wells had temperatures of 9 to 17°C. The warmer temperatures likely reflect sources of infiltration and recharge near these wells. MW-24 had the coldest temperatures of 9 to 10°C, which presumably results from the infiltration of cold treated wastewater effluent at the nearby Sewage Treatment Plant infiltration trenches.

Sr-90 was detected in all of the INTEC perched water wells during 2005. As in the past, very high Sr-90 concentrations (>10,000 pCi/L) were observed in the northern shallow perched water (Figure 4-13). The maximum Sr-90 concentrations detected in 2005 in the upper shallow perched zone were 188,000 pCi/L (MW-2); 159,000 pCi/L (33-1); 127,000 (ICPP-2018); 62,500 (MW-5-2); 36,500 (ICPP-2019); and 19,500 pCi/L (55-06). MW-20-2 and MW-10-2, completed in the lower shallow perched zone, also contained elevated Sr-90 at 19,500 and 13,100 pCi/L, respectively.

Several suction lysimeters in and around the tank farm permit sampling of pore water from the unsaturated alluvium. Lysimeters sampled during 2004 include four lysimeters inside the tank farm (A-60 series) and 16 lysimeters located elsewhere around INTEC (Figure 4-14). Samples collected from the suction lysimeters in 2004 generally contained far lower radionuclide concentrations than the perched water samples collected from nearby monitoring wells. For example, Sr-90 concentrations were <1 pCi/L in all four suction lysimeters at the tank farm sampled during 2004. This contrasts markedly with the elevated Sr-90 levels (>10,000 pCi/L) observed in shallow perched water monitor wells around the perimeter of the tank farm. Concentrations of Tc-99 and tritium did not exceed MCLs in any of the lysimeters. The 2004 annual perched water monitoring report (DOE-NE-ID 2004b) provides details regarding the lysimeter locations and water quality results.

Perched water samples have been periodically collected and analyzed for volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs). Laboratory results for selected organic compounds in perched water samples collected prior to 2003 are summarized in the Monitoring Well and Tracer Study (MWTS) report (DOE-ID 2003a). During 2003-2005, perched water samples have been collected quarterly as a requirement of the Waste Calcining Facility (WCF) Hazardous Waste Management Act (HWMA)/RCRA Post-Closure Permit. The WCF permit samples have been analyzed for a wide array of VOCs, SVOCs, and other miscellaneous organic compounds. These laboratory results are summarized in the WCF HWMA/RCRA Post-Closure Permit semiannual reports (DOE-NE-ID 2005b, DOE-NE-ID 2005c). Most VOCs and SVOCs were nondetect in all of the samples,

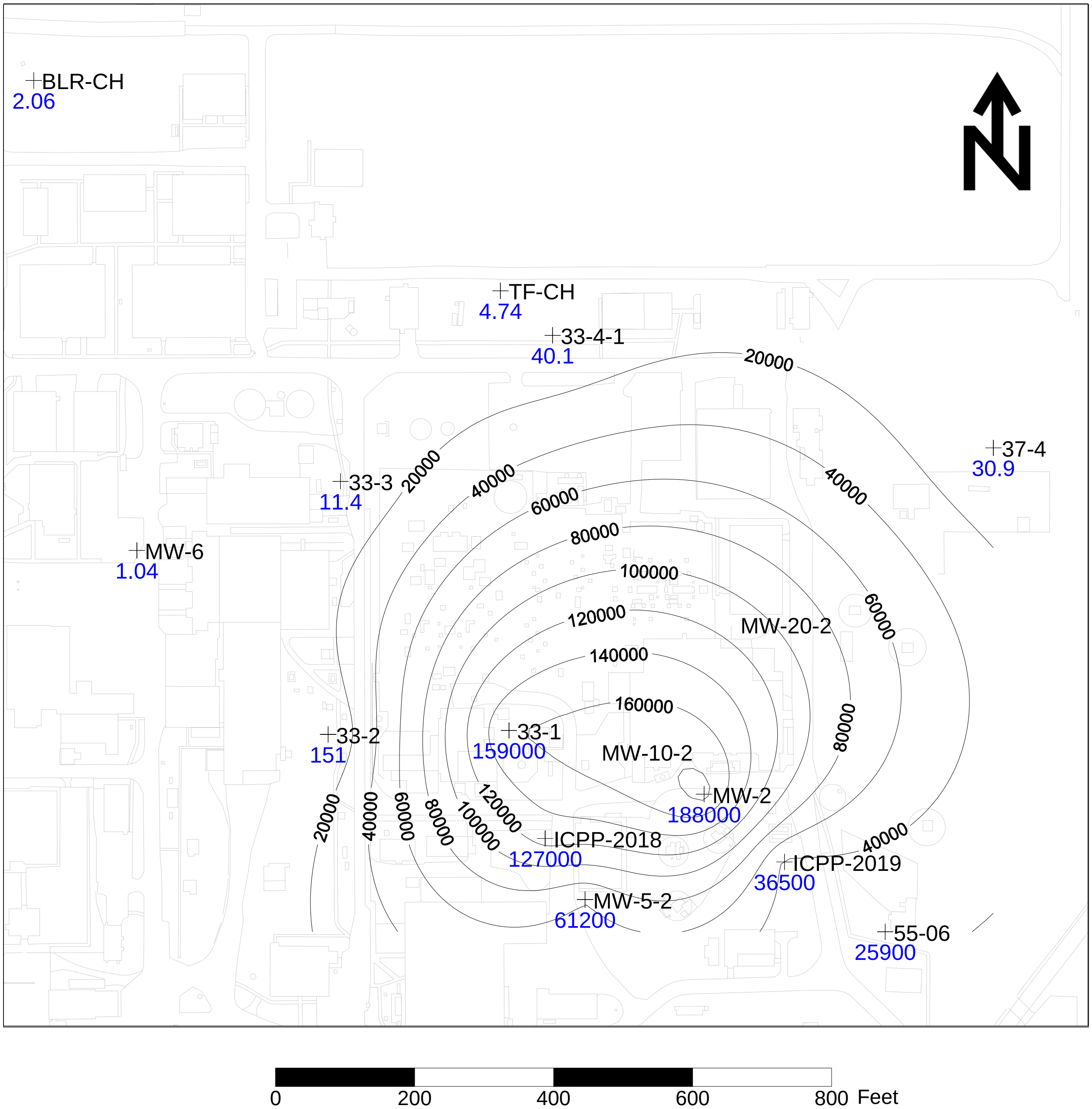

Figure 4-13. Sr-90 contour map (pCi/L) for northern shallow perched water in 2005.

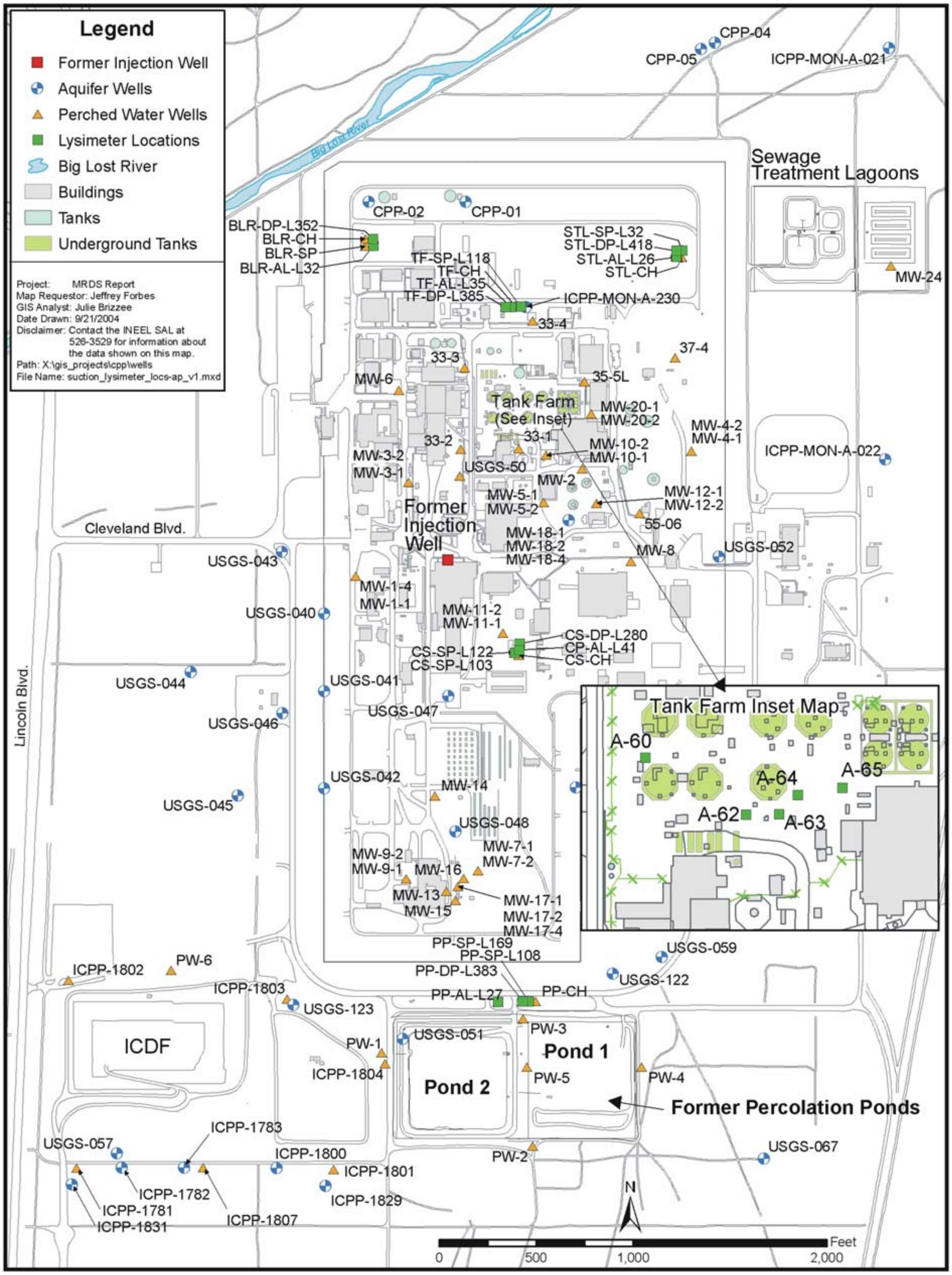

Figure 4-14. INTEC suction lysimeter locations.

but a few VOCs were occasionally detected at trace levels (<10 µg/L). These include toluene (2.3 µg/L in MW-2); trichloroethene (1.3 µg/L in Well MW-2, 1.2 µg/L in MW-5-2, 1.2 µg/L in CPP-33-1); tetrachloroethene (3.3 µg/L in MW-10-2); and dichlorodifluoromethane (CFC-12) (5.1 µg/L in MW-5-2). All of these concentrations are less than groundwater protection standards established in the WCF HWMA/RCRA Post-Closure Permit and less than the drinking water MCLs for these compounds. Therefore, the shallow perched water beneath INTEC clearly does not constitute a significant source of VOCs or SVOCs.

4.5.3.2 Northern Deep Perched Water. The deep perched water zone lies at depths of approximately 380 to 400 ft below surface and generally coincides with the 380-ft sedimentary interbed. Only a few monitoring wells have been completed in the northern deep perched water, including USGS-50, BLR-DP, TF-DP, STL-DP, and MW-18-1. Based on the limited number of wells, estimating the lateral extent and continuity of the deep perched water is difficult. MW-1-1 and MW-1-4 are completed at slightly shallower depths than the other deep perched water wells (359-369 and 326-336 ft bgs, respectively). The northern deep perched water contains contaminants derived primarily from service waste disposed of to the former INTEC injection well. In addition to the routine disposal of service waste to the aquifer from 1952 to 1984, the casing of the INTEC injection well is known to have failed twice, once in the late 1960s and again in the early 1980s, allowing service wastewater to flow out into the deep vadose zone (DOE-ID 2004c). Contamination of the deep perched zone also occurred for approximately 1 month during September-October 1970 when service waste was temporarily sent to deep perched monitor well USGS-50 during reconstruction of the injection well.

Deep perched water wells that contained enough water for sampling in 2004 include BLR-DP, MW-1-4, and USGS-50 (DOE-NE-ID 2004b). All other northern deep perched wells were either dry or did not contain enough water to sample. Water quality in the deep perched zone differs from that of the shallow perched water. Deep perched water historically has contained much less Sr-90 than the shallow perched water, but more tritium. The primary radionuclide contaminants in the deep perched water are Sr-90 and tritium. Elevated concentrations of tritium, Sr-90, and I-129 (and possibly Tc-99) in the deep perched zone are at least partially attributable to the former INTEC injection well (Site CPP-23), which received more than 1 mgd of low-level radioactive service waste from 1952-1984. Although analyses of Tc-99 concentrations in service waste were not performed during operation of the former injection well, the presence of a large Tc-99 plume in the SRPA downgradient of the injection well clearly demonstrates that Tc-99 was present in the service waste sent to the injection well (Beasley, Dixon, and Mann 1998). It follows that the service waste that entered the deep vadose zone during failure of the injection well during 1969-1970 also contained Tc-99 and that some of the Tc-99 observed in the deep perched water is likely attributable to the injection well source.

During 2004, Sr-90 and tritium were the only radionuclides in deep perched water that exceeded the MCL (DOE-NE-ID 2004b). The deep perched water from USGS-50 contained Sr-90 at 118 pCi/L, which exceeds the MCL (8 pCi/L), but Sr-90 levels in this well have declined significantly from those observed during the early 1980s when the injection well was still in operation. Sr-90 levels in 2004 were less than the MCL in deep perched water wells BLR-DP (nondetect) and MW-1-4 (5.4 pCi/L).

None of the deep perched water wells has ever exceeded the Tc-99 MCL of 900 pCi/L. The highest Tc-99 concentration reported for the deep perched water was 736 pCi/L at monitoring well MW-18-1 in 1995. Well USGS-50 formerly contained Tc-99 at concentrations up to 77 pCi/L during the early 1990s, but Tc-99 concentrations have declined in this well since 1994, when repairs were made to reduce downward cascading of water in the well bore. In 2004, the Tc-99 concentration in USGS-50 was 31 pCi/L.

From 2000 to 2005, I-129 concentrations have remained below the MCL (1 pCi/L) in the deep perched water wells. The only deep perched water well in which I-129 was detected was USGS-50

(0.569 pCi/L). This value is slightly lower than that observed in the past in this well (0.62 pCi/L in 2001). Low but persistent I-129 concentrations in the deep perched water are most likely attributable to the combined impacts of poor quality shallow perched water from the tank farm area and drain out of service waste discharged to the deep vadose zone before 1984 at the former INTEC injection well.

USGS-50 contained tritium at 21,300 pCi/L in 2004. Tritium concentrations over time in USGS-50 show a clear and steady decline in tritium over the past 20 years since the former INTEC injection well was taken out of service (DOE-NE-ID 2004b). The rate of decline exceeds that predicted by radioactive decay alone, and the difference is probably attributable to a combination of hydrodynamic dispersion and flushing/advection of deep perched water. Tritium activities in the other deep perched wells were less than the MCL of 20,000 pCi/L. During 2004, nitrate concentrations exceeded the MCL (10 mg/L as N) in two of the deep perched wells: MW-1-4 (52 mg/L) and USGS-50 (27 mg/L). The concentration of nitrate in MW-1-4 continues to show a trend of slowly declining nitrate concentrations (see Figure B-7 in DOE-ID 2003c).

4.5.3.3 Shallow Perched Water Levels and Hydraulic Gradients. Perched water levels are measured manually on a monthly basis, and many of the monitoring wells are equipped with automated water level instruments that collect data every 30 minutes. Unlike wells completed in the SRPA, hydrographs for perched water wells vary widely from well to well, with rising water levels in some wells while others are declining. Recent trends in perched water levels are discussed in the 2004 Group 4 perched water monitoring report (DOE-NE-ID 2004b).

Perched water tends to flow vertically downward but may flow laterally where low-permeability units are present that impede downward flow. Compared with groundwater flow in the underlying SRPA, flow paths in the perched water can be tortuous and difficult to predict. Nimmo et al. (2004) have summarized the complexity of water flow in the vadose zone at the INL Site.

Figure 4-15 shows interpolated shallow perched water level contours near the tank farm for May 2005. The perched water elevation data suggest that lateral flow in the shallow perched water beneath the northern INTEC area is generally to the southeast. The water level contour maps also show a flattening of the hydraulic gradient in the vicinity of MW-2 and MW-5-2. It should be emphasized that downward vertical flow is also expected for the shallow perched water, but such vertical flow cannot be deduced from the contour map of water levels. Shallow perched water levels measured during 2004-2005 indicate southeasterly hydraulic gradients ranging from <0.01 to approximately 0.02 ft/ft. A constant-rate pumping test performed on MW-5-2 during 1995 indicated a horizontal hydraulic conductivity (K_H) of approximately 1.3×10^{-3} cm/s (DOE-ID 1997). Current estimates of the effective porosity of the fractured basalt range from 0.03 to 0.05. Assuming the latter value and substituting the previous values into Darcy's Equation give the following estimate of perched water average linear velocity:

$$V_H = (K_H * I) / n = (1.3 \times 10^{-3} \text{ cm/s} * 0.02) / 0.05 = 5.2 \times 10^{-4} \text{ cm/s} = 0.5 \text{ m/day}$$

where

V_H = average linear water velocity (cm/s)

K_H = horizontal hydraulic conductivity (cm/s)

I = horizontal hydraulic gradient (dimensionless)

n = effective porosity (dimensionless).

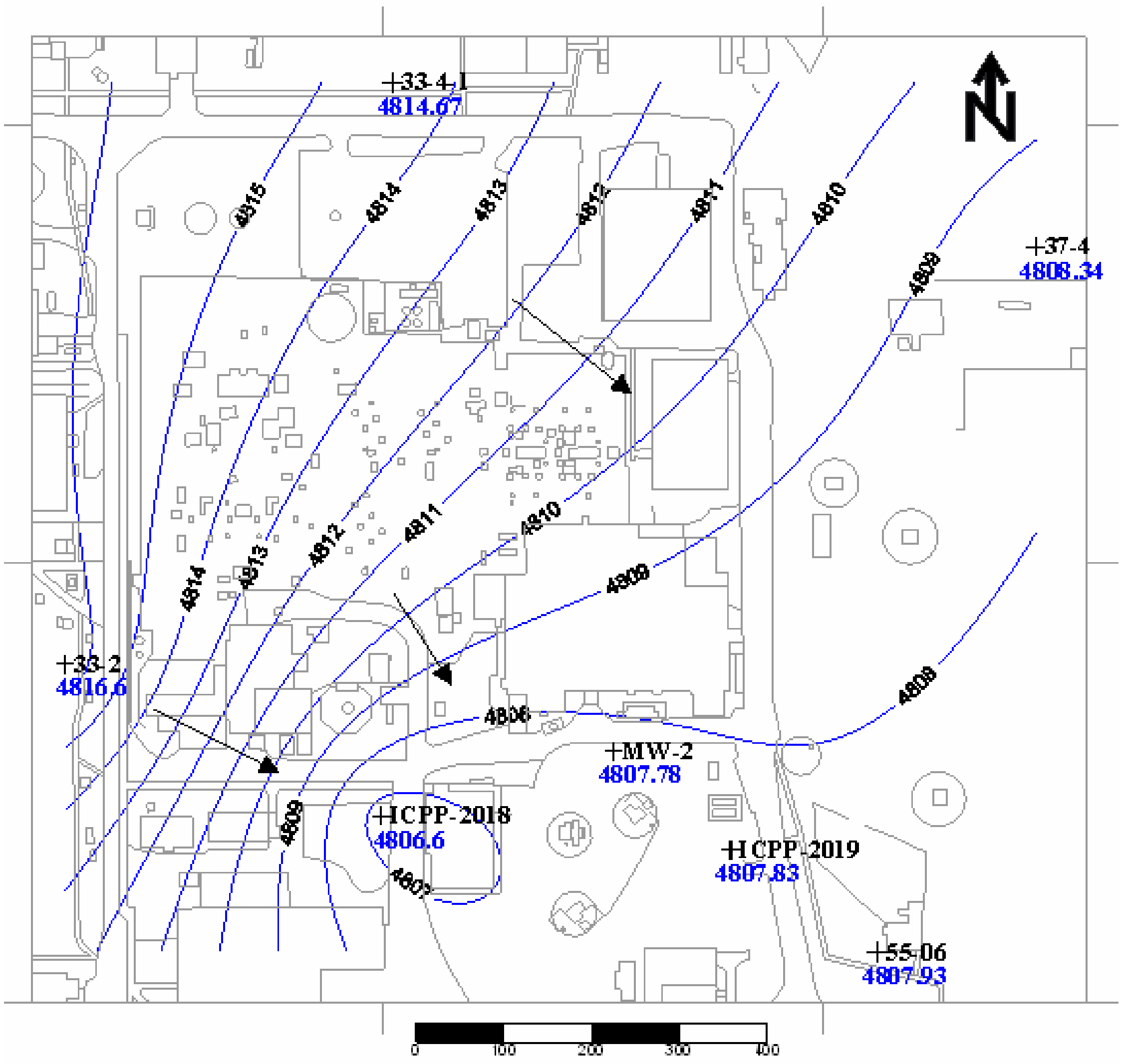

Figure 4-15. Upper shallow perched water level contours for May 16, 2005.

This calculation suggests perched water horizontal average linear flow velocities of up to 0.5 m/day. It should be recognized that this calculation assumes an isotropic, porous medium, and this assumption is not valid for the fractured basalt. Actual average linear flow velocities through joints in the basalt could be considerably faster than the calculated 0.5 m/day. In addition, these calculations are based on the assumptions that the wells selected are hydraulically connected and are completed in the same continuous perched water zone. Because of uncertainties regarding these assumptions, the flow calculations should be used with caution.

4.5.3.4 Southern Perched Water. Although perched water was present in the southern portion of INTEC as early as 1963 (Robertson, Schoen, and Barraclough 1974), significant volumes of perched water accumulated in this area starting in 1984 when the former percolation ponds began receiving service wastewater.

The northern extent of the southern perched water generally coincided with the southern INTEC fence line (DOE-ID 2003a). The principal zones of southern perched water that have been observed are (1) intermittent perched water in the alluvium at the top of basalt at 30 ft bgs, (2) shallow perched water at the 110-ft interbed, (3) intermediate perched water at a low-permeability basalt or interbed at 250 ft bgs, and (4) deep perched water at the 380-ft sedimentary interbed. A detailed discussion of the accumulation and subsequent dissipation of perched water near the former percolation ponds is given in Cahn and Ansley (2004), and the 2003 Group 4 perched water monitoring report (DOE-ID 2003c) provides a discussion of water level responses during drain out.

As of 2004, nearly all of the shallow perched water monitor wells near the former percolation ponds were dry. By August 2003, all of the PW-series wells around the former percolation ponds had gone dry except for PW-4 (Figure 4-9). As of February 2005, this well still contained approximately 26 ft of water, and the water level continued to slowly decline over time. PW-4 appears to be completed in a location where the perched water can only drain away very slowly, perhaps in a topographic low point atop the 140-ft sedimentary interbed. Drain out of the deep perched zone continues to be monitored under the Idaho CERCLA Disposal Facility monitoring program, and, as of 2005, only ICPP-1804L still contains remnant percolation pond water.

The following perched water wells in the central and southern part of INTEC contained water in 2004: MW-7-2, MW-9-2, MW-17-2, CS-CH, and ICPP-1804 (Figure 4-9). Perched water level and quality are reported in the Idaho CERCLA Disposal Facility perched water analysis report (Cahn and Ansley 2004) and the OU 3-13 Group 4 annual perched water monitoring report (DOE-NE-ID 2004b is the most recent).

Perched water quality near the south edge of the INTEC facility generally shows the geochemical signature of the service waste previously discharged to the former percolation ponds. The service wastewater that was sent to the former percolation ponds had relatively high chloride concentrations (>200 mg/L). Like the service waste, the perched water in this area also contains elevated concentrations of sodium and chloride. However, the relatively low chloride concentrations observed at Wells MW-7-2 and MW-17-2 (Figure 4-9) suggest that the influence of the former percolation ponds did not extend as far north as these two wells. Unlike the northern shallow perched water, nitrate was not elevated above its MCL in any of the central or southern perched water wells (DOE-NE-ID 2004b).

Tritium exceeded the MCL (20,000 pCi/L) in two perched water wells: MW-17-2 (182 to 192 ft; 33,800 pCi/L); nearby shallow perched water well MW-7-2 displayed a slightly lower tritium activity of 27,300 pCi/L. These levels represent the highest tritium activities currently observed in perched water at INTEC (see Figure A-6 in DOE-NE-ID 2004b). Concentration trends for these wells show declining tritium concentrations from 2001 to 2004.

Historically, Sr-90 and Tc-99 have also been detected in perched water monitoring wells near the former CPP-603 fuel storage basins (INEL 1995b). During 2004, however, reported concentrations of Sr-90 and Tc-99 were very low or nondetect in those wells that contained sufficient water for sampling (MW-7-2, MW-9-2, and MW-17-2). Likewise, Am, Np, and Pu were not detected in any of these wells during 2004, nor were any of the gamma-emitting radionuclides.

4.5.4 Nature and Extent of Snake River Plain Aquifer Contamination

The SRPA underlies the entire INL Site, and is among the nation’s most productive aquifers. It is the primary source of water for domestic, municipal, and industrial use in southeastern Idaho and also provides large quantities of water for agricultural irrigation (along with surface water from the Snake River). The SRPA consists of a thick sequence of Quaternary basalt flows, some of which are separated by thin sedimentary interbeds deposited at the land surface during the intervening periods between volcanic eruptions. Section 4.3 summarizes the geology at INTEC and the INL Site.

Groundwater flow in the SRPA occurs predominantly through fractures (joints) in the basalt and along rubble zones at flow contacts (bedding planes). In the eastern SRPA, regional groundwater flow is to the southwest. Recharge occurs primarily in mountain-front areas near the Yellowstone Plateau and Lost River Ranges. Lesser recharge sources include seepage into the bed of the BLR (when flowing) and infiltration of irrigation water applied to agricultural lands near Howe and Mud Lake to the north and northeast of the INL Site, respectively. The groundwater then flows southwest toward discharge areas at Thousand Springs near Hagerman. On a local scale, groundwater flow directions may differ from regional flow paths as a result of fracture orientations. Details of regional hydrogeology of the SRPA are given in Robertson, Schoen, and Barraclough (1974); INEL (1995b); and Smith (2004).

Hydraulic conductivities in the SRPA near INTEC commonly exceed 1,000 ft/day (0.35 cm/s), with a maximum value of 8,800 ft/day (3.1 cm/s) at the former INTEC injection well (Anderson, Kuntz, and Davis 1999). Hydraulic conductivities beneath INTEC are among the highest anywhere in the INL Site. The very large hydraulic conductivities and fractured nature of the basalt aquifer matrix result in very rapid groundwater flow velocities, typically 5 ft/day near INTEC. Based on observations of tritium migration from the former injection well, it is known that even higher flow velocities occurred when the injection well was in operation (1952-1984) (Robertson, Schoen, and Barraclough 1974).

There has been debate regarding the thickness of the actively flowing portion of the SRPA. Estimates range from 250 ft (76 m) (Robertson, Schoen, and Barraclough 1974; WAG 3 model, see Appendix A) to 660 ft (200 m) (WAG 10 model, DOE-ID 2006b). A discussion of the bases for the various estimates is found in the WAG 3 RI/FS Work Plan (INEL 1995b). However, permeabilities generally decline with depth in the aquifer, so it is not possible to define a distinct “base” for the aquifer. The current best estimate of the effective porosity of the SRPA is 3%, which is based on model calibration to tritium concentrations in the aquifer derived from the former injection well (Appendix A). This value is considerably lower than previous estimates ranging from 5% to 15%.

Based on isotopic and groundwater temperature data, the INTEC facility appears to be located above a “fast path” in the underlying SRPA, with a tongue of fast-moving, cold groundwater flowing south under this area (Johnson et al. 2000; Roback et al. 2001). The fast path presumably corresponds with a more permeable zone in the SRPA, which is consistent with the results of pumping tests for wells in the INTEC area (Anderson, Kuntz, and Davis 1999). Frederick and Johnson (1997) have shown significant vertical variation in groundwater quality within a single well.

The upper portion of the SRPA is generally considered to be an unconfined (water table) aquifer. However, due to low storage coefficient of the fractured basalt aquifer, the SRPA behaves more like a confined aquifer in some respects. For example, rapid vertical flow reversals have been observed in monitoring well USGS-59 in response to cycling of INTEC water supply wells located approximately 4,000 ft away (CPP-01 and CPP-02) (Frederick and Johnson 1997). Similar flow reversals were observed in USGS-46 when production well CPP-02 was turned on and off (Morin et al. 1993).

4.5.4.1 SRPA Groundwater Quality. Beginning in 1952, groundwater quality at and downgradient (south) of INTEC has been impacted by facility operations. The most significant water quality impacts resulted from the former INTEC injection well. The injection well (CPP-03) was routinely used to discharge INTEC service wastewater to the aquifer from 1952 to February 1984, when it was taken out of service as the percolation ponds became operational. During its operation, the injection well constituted a source of low-level radioactivity to the aquifer. The principal radionuclides of environmental significance discharged to the injection well were tritium (H-3), strontium-90 (Sr-90), iodine-129 (I-129), cesium-137 (Cs-137), and technetium-99 (Tc-99).

The history of the former INTEC injection well was summarized in EDF-3943. Discharge of service waste to groundwater through the injection well resulted in a groundwater plume containing elevated concentrations of tritium, Sr-90, Tc-99, sodium, chloride, and other solutes. During the 1970s through the 1990s, concentrations of tritium, Sr-90, and I-129 in groundwater exceeded drinking water standards at numerous monitoring wells located at and downgradient of INTEC (DOE-ID 2004c). By the early 1990s, low but detectable concentrations (below MCLs) of tritium, Cl-36, Tc-99, and I-129 derived from the injection well had reached the southern INL Site boundary some 8 mi south of INTEC (Beasley et al. 1993; Beasley Dixon, and Mann 1998). In addition to the routine disposal of service waste to the aquifer from 1952 to 1984, the casing of the INTEC injection well is known to have failed twice, once in the late 1960s and again in the early 1980s, allowing service wastewater to flow out into the vadose zone (DOE-ID 2004c). Contamination of the deep perched zone also occurred for approximately 1 month during September-October 1970 when service waste was temporarily sent to deep perched monitor well USGS-50 during reconstruction of the injection well.

Since it was taken out of service in 1984, the former INTEC injection well no longer constitutes a continuing source of contaminants to the aquifer. However, drain out of service waste from the deep perched zone continues to contribute a slow flux of tritium, Sr-90, I-129, and other radionuclides to the SRPA (DOE-ID 2004c). As of 2003, tritium and I-129 activities (derived from the injection well) were already below their respective MCLs in all SRPA monitor wells downgradient of INTEC. Therefore, remedial action objectives for these two constituents have already been met. During 2003 and 2004, Sr-90 concentrations in groundwater continued to exceed the MCL (8 pCi/L) downgradient of INTEC (Figure 4-16), but concentrations in most monitoring wells appear to be slowly declining as a result of radioactive decay and dilution/dispersion (Figure 4-17). Current trends indicate that Sr-90 concentrations in the plume derived from the former injection well source will decline below the MCL before the year 2095 (DOE-ID 2004c).

In May 2003, routine groundwater monitoring at new aquifer monitor well ICPP-MON-A-230 near the northern boundary of the INTEC showed that Tc-99 was present in the SRPA at concentrations approximately three times the derived MCL for Tc-99 of 900 pCi/L. This was the first time that Tc-99 concentrations in the aquifer had been found to exceed the MCL. As a result of the unexpected Tc-99 level in groundwater, an investigation was performed during 2003 to determine the source of the Tc-99. Figure 4-18 shows Tc-99 concentrations in the SRPA in 2004 and Figure 4-19 shows Tc-99 concentrations over time for selected INTEC wells. The results of the Tc-99 investigation indicated that the source of the elevated Tc-99 in groundwater at Well ICPP MON-A-230 was most likely attributable to historical liquid waste releases at the tank farm, in particular the Site CPP-31 release (ICP 2004). The preponderance of evidence argues against the hypothesis that an improper annular seal at monitoring well ICPP-MON-A-230 could have allowed rapid downward migration of Tc-99 along the borehole to the aquifer. The 2005 Tc-99 results from new aquifer well ICPP-2021 (located 1,500 ft away from MON-A-230) demonstrates that elevated Tc-99 concentrations are more widespread in the SRPA than previously believed. Moreover, the lack of elevated Tc-99 concentrations in the shallow perched water (TF-CH) and deep perched water (TF-DP-L385) at the Tank Farm Well Set suggests that the source of the elevated Tc-99 in the aquifer most likely cannot be attributed to downward leakage of perched water at the boreholes of the Tank Farm Well Set. Therefore, the most likely mechanism for transport of Tc-99 from contaminated tank farm soils to the aquifer is believed to be downward movement of contaminated water through the vadose zone to the water table, not short-circuiting down the borehole at Well ICPP-MON-A-230. Although the former INTEC injection well likely constituted an earlier source of Tc-99 to the aquifer, the resulting concentrations of Tc-99 in groundwater did not exceed the MCL (900 pCi/L).

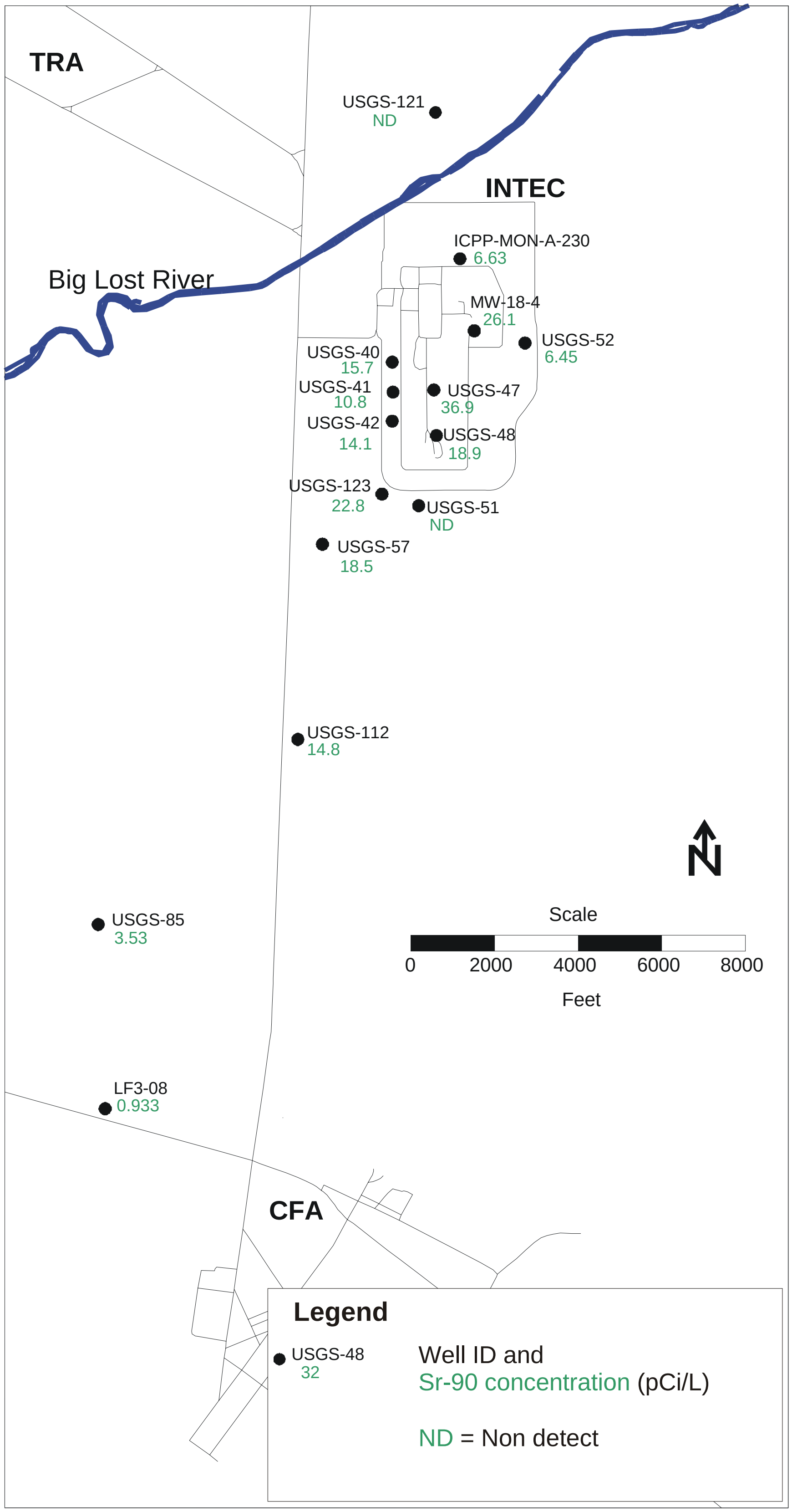

Figure 4-16. Distribution of Sr-90 in groundwater - 2004.

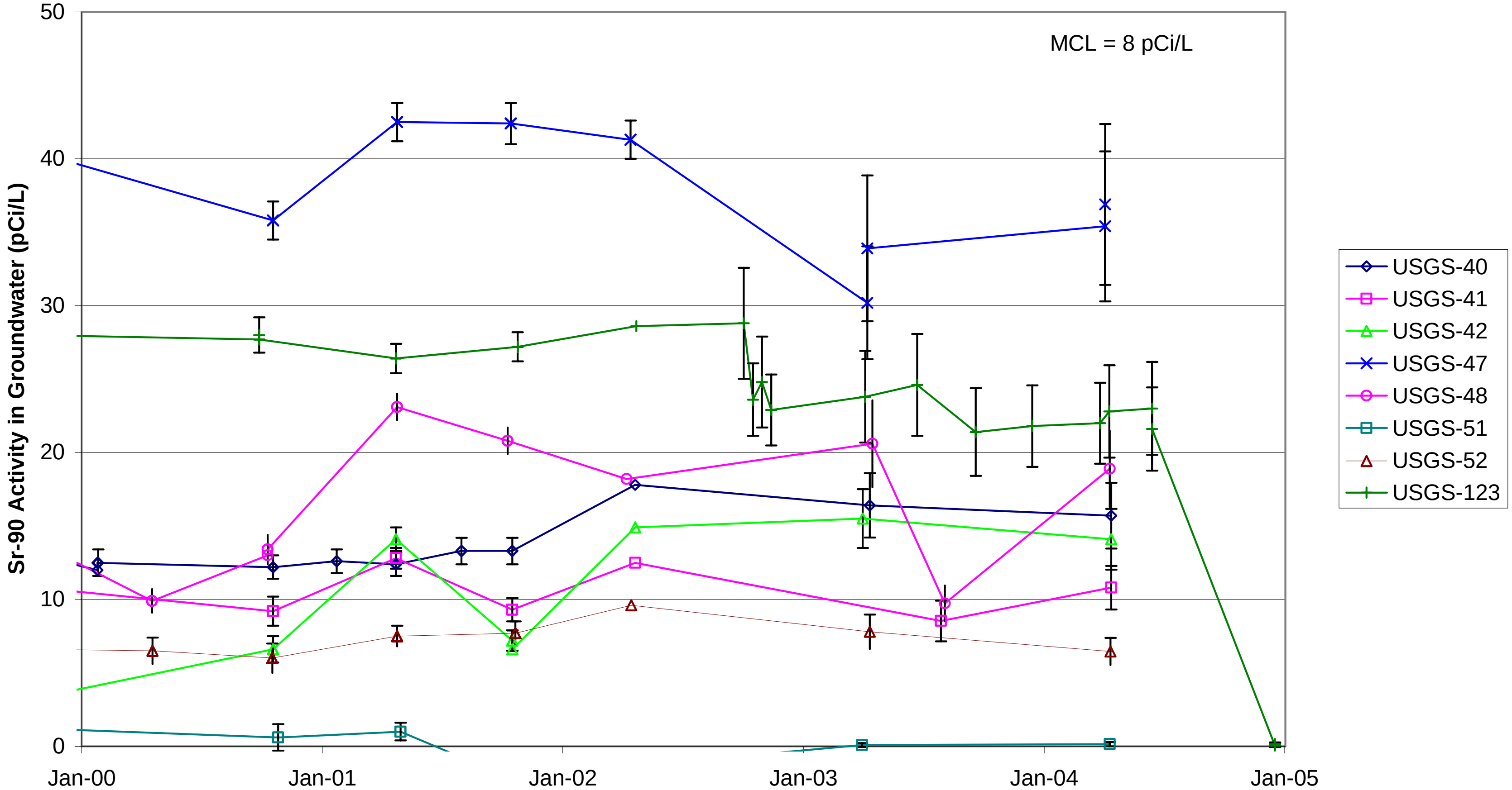

Figure 4-17. Sr-90 concentration trends for selected wells.

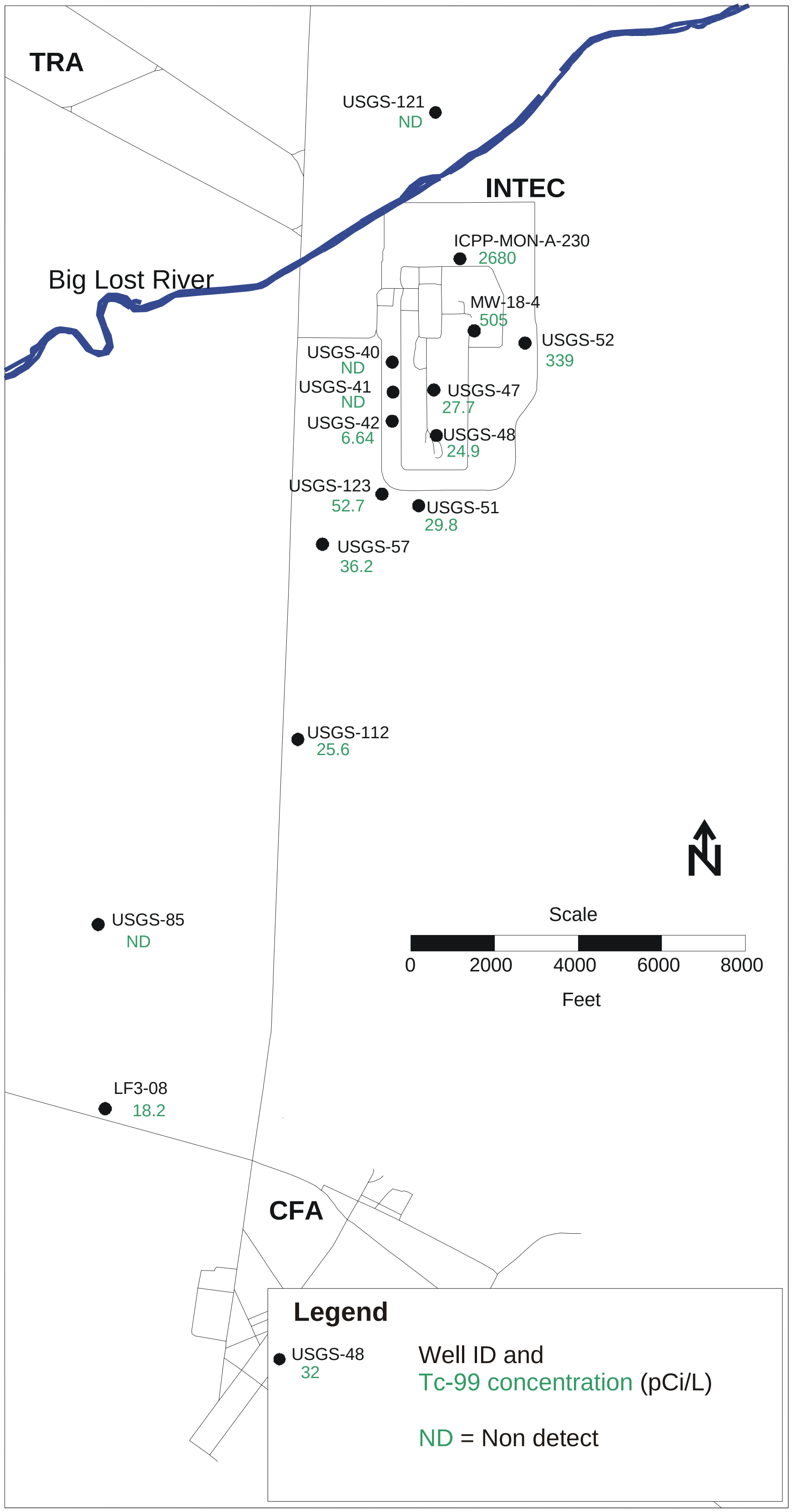

Figure 4-18. Distribution of Tc-99 in groundwater - 2004.

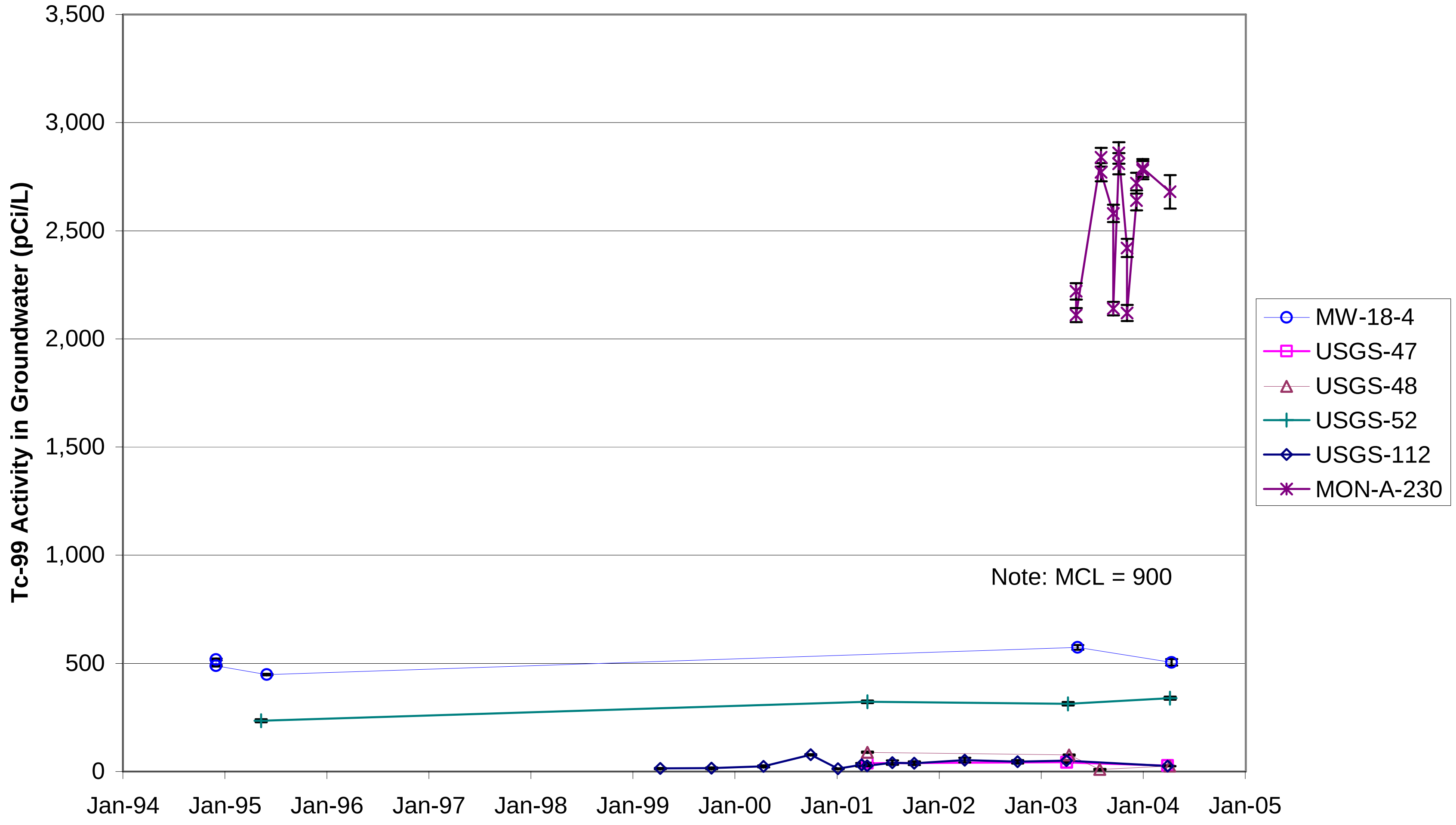

Figure 4-19. Tc-99 concentration trends for selected wells (error bars shown).

During 2005, Sr-90, Tc-99, I-129, and nitrate exceeded their respective drinking water MCLs in one or more of the monitoring wells at or near INTEC. Sr-90 concentrations exceeded the MCL (8 pCi/L) in nine of the 18 monitoring wells. Cs-137 was detected in groundwater samples from two of the wells, but the concentrations were far below the MCL (200 pCi/L). It should be emphasized that the monitoring wells are not used for drinking water, and comparison with MCLs is for reference only. Tc-99 was detected above the MCL (900 pCi/L) in two wells within INTEC, but concentrations were below the MCL at all other locations. In 2005, one well slightly exceeded the I-129 MCL of 1 pCi/L. C-14 was detected in four of the 15 monitoring wells sampled in 2004, but C-14 concentrations were all far below the MCL (2,000 pCi/L).

In contrast to the fission products, none of the actinide elements (U, Pu, Np, Am) have ever exceeded their MCLs in groundwater at or downgradient of INTEC. Pu-241 was the only plutonium isotope detected in groundwater during 2004. Pu-241 was detected at 20.6 pCi/L in one well within INTEC (USGS-48), but the concentration was well below the derived MCL of 300 pCi/L. Am-241 was not detected in any of the samples, and Np-237 was only detected in a single well (USGS-47) at a concentration of 0.178J ±0.0638 pCi/L, which was close to the detection limit. Activities of U-233/234, U-235, and U-238 isotopes were similar to background concentrations.

Nitrate was detected in all of the WAG 3 aquifer wells sampled during 2004 and 2005. During 2004, the highest nitrate/nitrite-nitrogen concentrations were observed at Wells USGS-40 (11 mg/L) and USGS-41 (11.2 mg/L), located near the former injection well, and ICPP-MON-A-230 (9.2 mg/L), located north of the tank farm. During 2005 the highest concentrations were reported at new aquifer well ICPP-2021 (13.2 mg/L as N), ICPP-MON-A-230 (7.7 mg/L), and MW-18-4 (7.3 mg/L). All three of these wells are located near the tank farm, and all show groundwater quality impacts attributed to past tank farm liquid waste releases. The nitrate-nitrogen concentration at several locations has slightly exceeded the nitrate-nitrogen MCL of 10 mg/L (as N). On the basis of a comparison of nitrate/Tc-99 ratios observed at Well ICPP-MON-A-230 with the ratios in tank farm liquid wastes and in service waste, the source of the elevated nitrate at that well appears to be primarily from past tank farm releases, not the former injection well (ICP 2004).

During 2004, mercury was detected at two monitoring wells, but the concentrations were below the MCL of 2 µg/L. Nitrate concentrations in groundwater slightly exceeded the MCL at two of the wells within INTEC. The elevated nitrate levels are believed to result from service waste previously discharged to the former injection well. Elevated chloride concentrations persist in groundwater in the vicinity of the former percolation ponds as a result of the elevated salinity of the service waste previously discharged to the ponds, but concentrations have declined since use of the former percolation ponds was discontinued in August 2002.

Groundwater monitoring results for 2004 and 2005 confirm previous observations that the concentrations of most radionuclides in groundwater continue to decline over time. Sr-90 concentrations remain above the MCL (8 pCi/L) at nine of the 16 monitoring wells sampled in 2004, but Sr-90 levels have declined at most locations from the concentrations that were observed in 2001 and 2003. Tritium and I-129 concentrations were below MCLs in all wells sampled during 2003 and 2004, but I-129 exceeded the MCL in one well during 2005. I-129 concentrations increased slightly in several wells since 2001, but trends are inconclusive. Between 2001 and 2004, Tc-99 concentrations in groundwater have increased slightly at several locations downgradient of INTEC (DOE-ID 2002b; DOE-ID 2003d; DOE-NE-ID 2004b).

Groundwater samples have been periodically collected and analyzed for VOCs and SVOCs. Laboratory results for organic compounds in the SRPA at and downgradient of INTEC were summarized in the Monitoring Report/Decision Summary (MRDS) (DOE-ID 2004c). This document also evaluated the potential that the former INTEC injection well may have received organic compounds in the service waste that was discharged to the aquifer. Most VOCs and SVOCs were nondetect in all of the groundwater samples, but a few VOCs were occasionally detected at trace levels (<10 μg/L) in groundwater. These include toluene (8.6 μg/L in ICPP-1831, 6.5 μg/L in ICPP-1782); 1,1,1-trichloroethane (0.7 μg/L in USGS-51, 0.6 μg/L in USGS-67); trichloroethene (0.99J μg/L in USGS-47). All of these concentrations are less than the drinking water MCLs for these compounds. Therefore, it is clear that there is no actionable groundwater VOC or SVOC plume at or immediately downgradient of INTEC.

4.5.4.2 SRPA Groundwater Levels. During June 2004, water levels were measured in 70 aquifer wells in the vicinity of INTEC and CFA to evaluate groundwater flow directions (DOE-NE-ID 2004b). Depths to water in SRPA monitoring wells at INTEC were approximately 470 ft below land surface. Water level measurements indicate groundwater flow is to the south-southwest. The hydraulic gradient between INTEC and CFA is extremely flat (<0.0002 ft/ft), which reflects the very large hydraulic conductivity of the fractured basalt aquifer that underlies the area.

The 2004 groundwater level contour map shows that the general direction of groundwater flow near INTEC is south to southwest (Figure 4-20). Near CFA, the flow ranges from southeast to southwest. The groundwater hydraulic gradient varies considerably across the map area. The gradient is relatively flat between INTEC and the CFA landfill wells (LF-series wells), with less than 2 ft of head difference over this 2-mi distance. Steeper gradients exist south of CFA and in the vicinity of the Critical Infrastructure Test Range Complex (formerly the Power Burst Facility) southeast of INTEC. The 2004 groundwater map is similar in shape to that for 2003 (DOE-ID 2003d), except that groundwater levels in 2004 are approximately 1 ft lower on average. During periods of high flow in the BLR, local groundwater levels and the direction of groundwater flow can be temporarily altered by recharge from the river. In periods of low flow in the BLR, local gradients reflect regional flow directions.

Figure 4-21 shows groundwater hydrographs for selected aquifer wells for the period 1966-2004. Groundwater levels and the configuration of the water table vary in response to changes in the volume and source of recharge. Water levels peaked in the early 1970s during a prolonged period of above-average precipitation and high flows in the BLR beginning in 1965. Water levels subsequently declined during a period of average or below-average precipitation and stream flow beginning in 1976 and continuing through the early 1980s. Water levels rose again during the period from 1981 through 1985, corresponding with a period of flow in the BLR. Peak groundwater levels generally occurred approximately 1 year after each period of high flow in the river. During the current drought cycle of no BLR flow (2000 through 2004), groundwater levels have declined more than 10 ft in many aquifer wells across the southern INL Site.

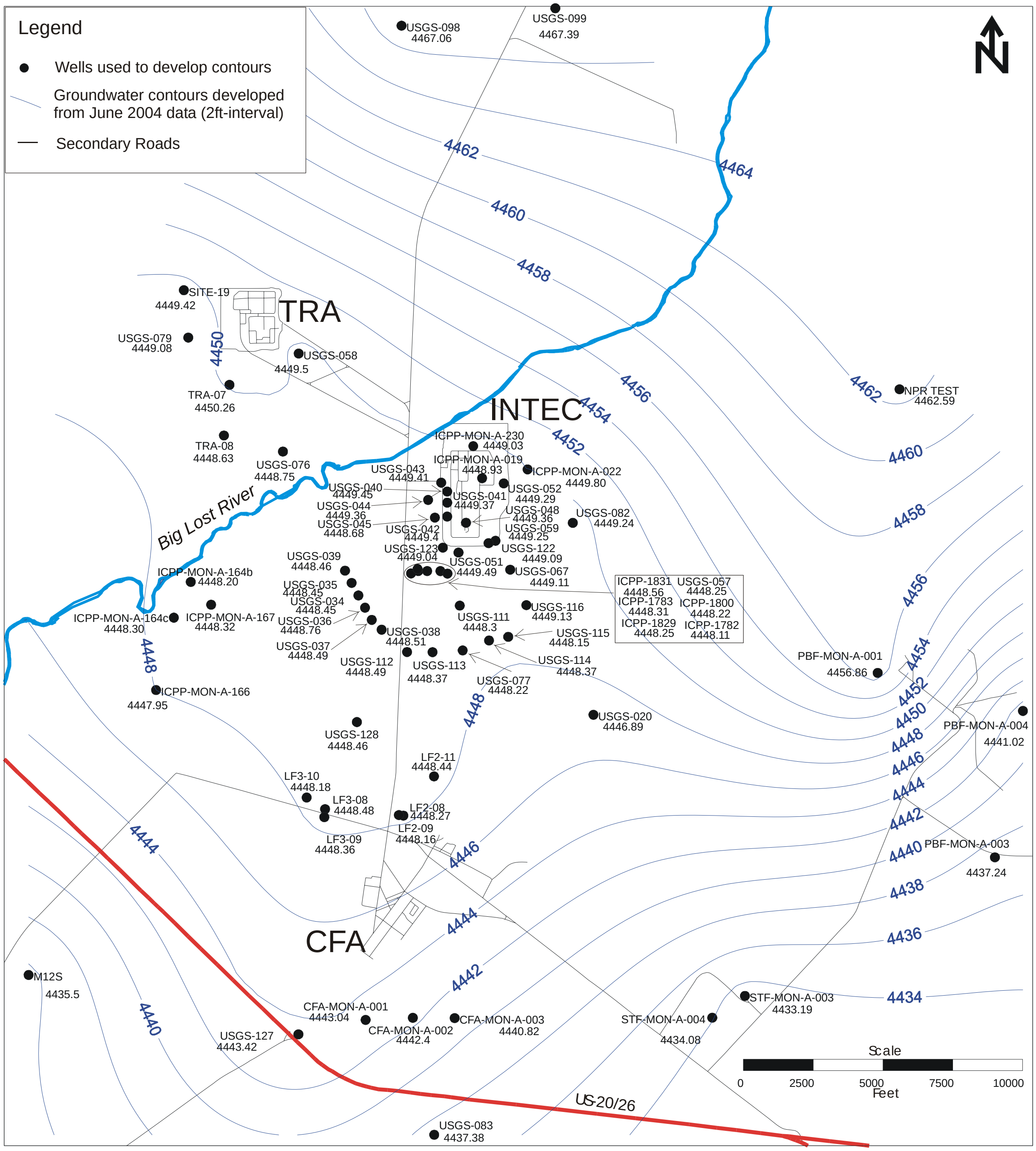

Figure 4-20. Groundwater elevation contour map—June 2004.

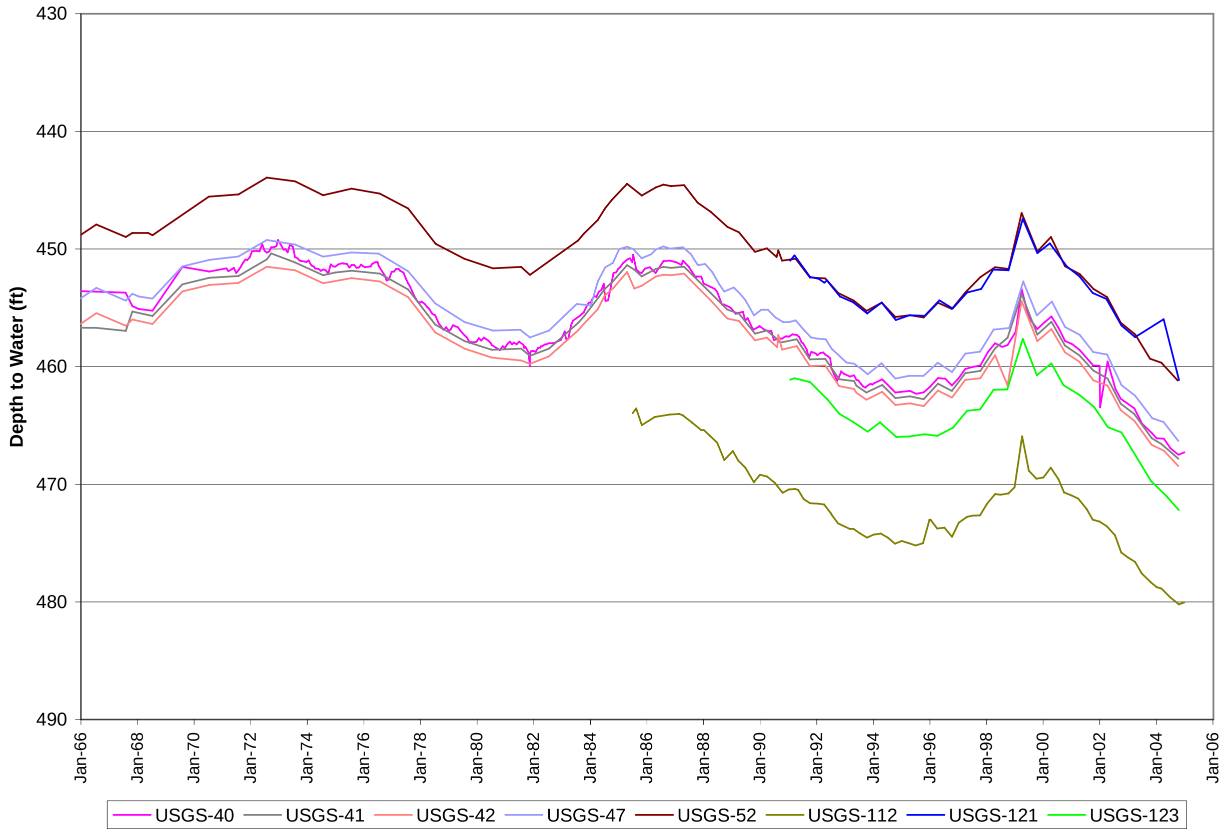

Figure 4-21. Hydrographs for selected wells.

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